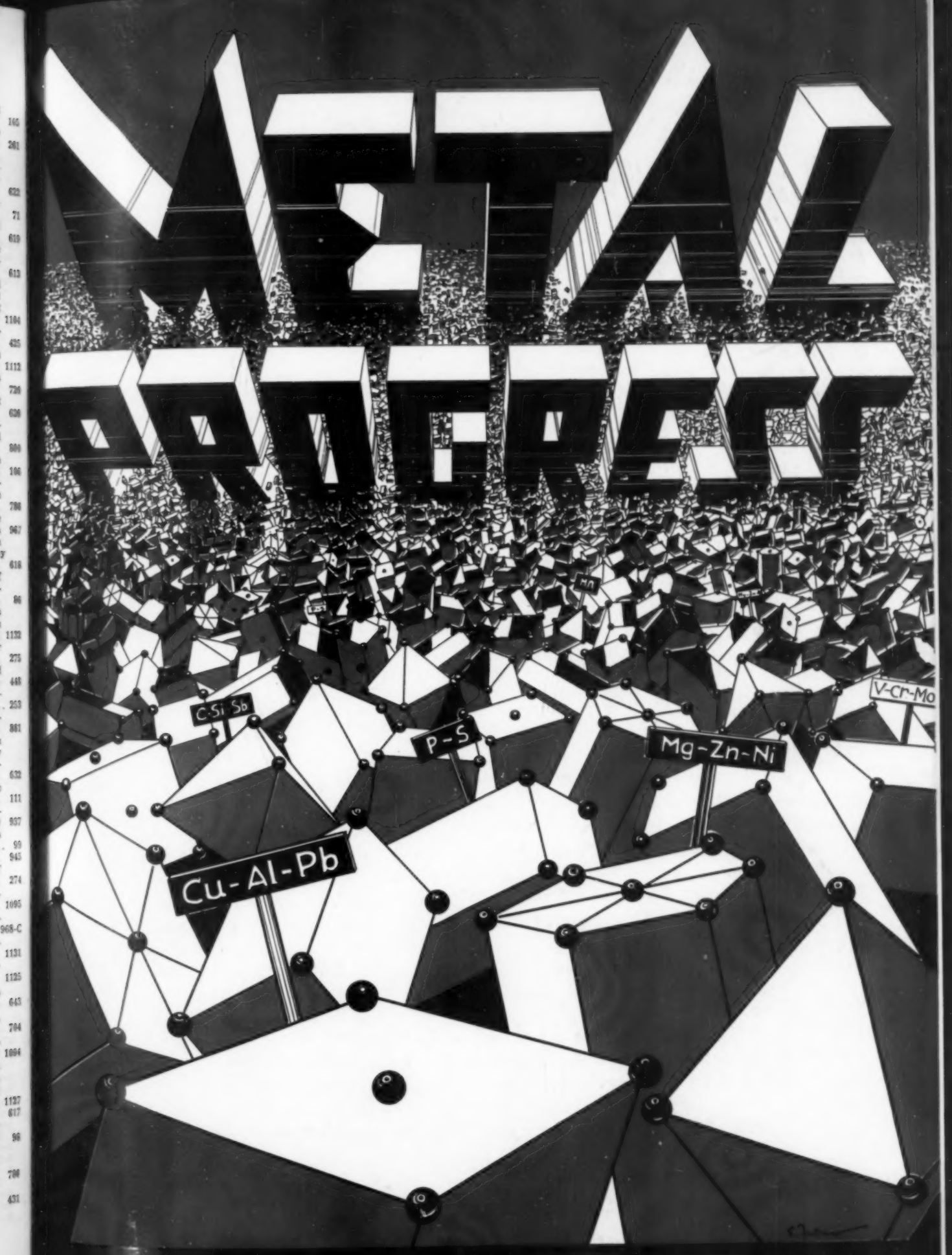

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METAL PROGRESS

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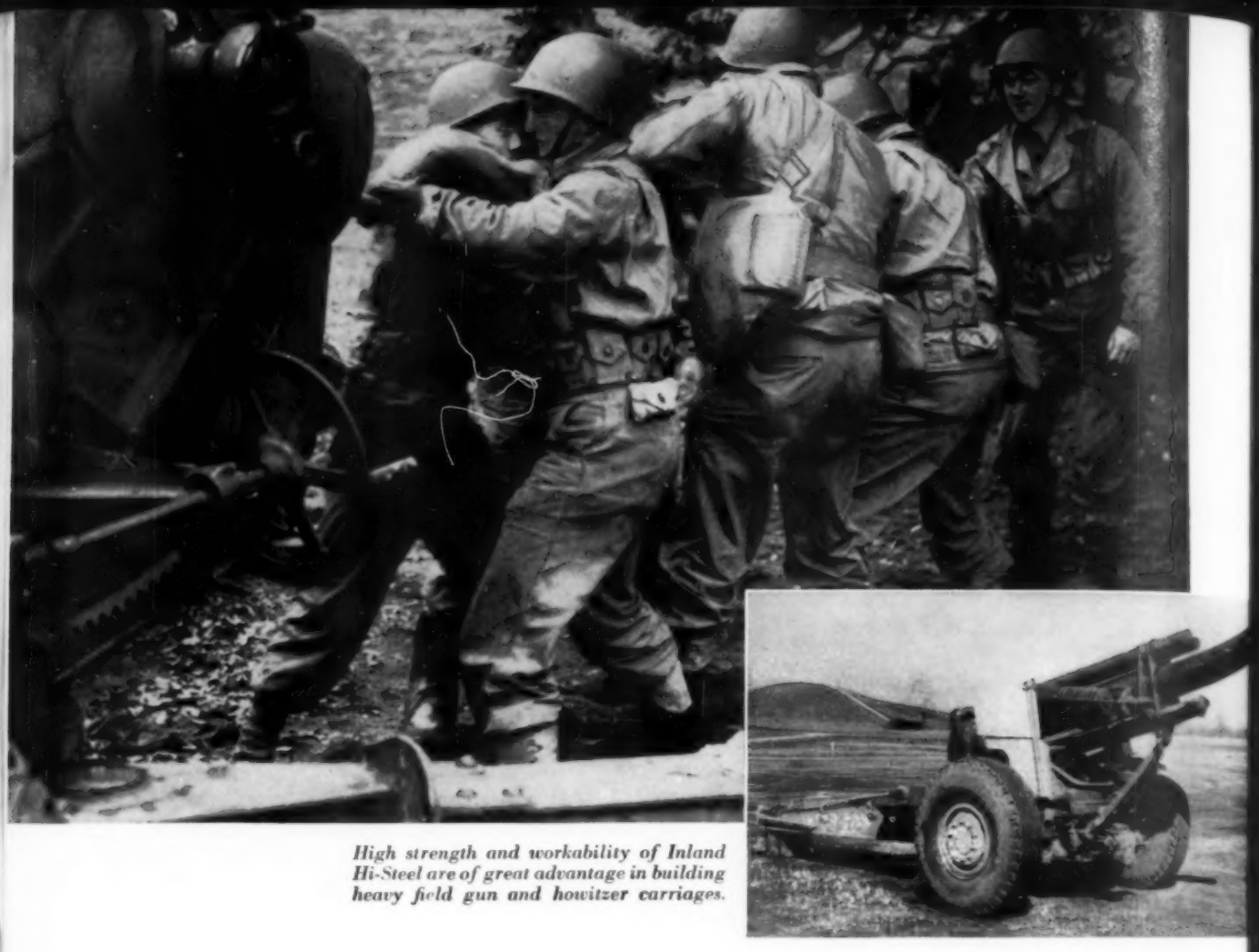

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During a period when the machine-shop efficiency was increasing by 35%, despite large expansion in plant and personnel, a study was made of the incoming steel, heat by heat, and a method devised whereby the machinability rating can be predicted from its tensile properties. The method possesses sufficient generality to be useful either for adjusting speeds or feeds to match the properties of the specific steel delivered, or for raising the general level of machinability by correcting aberrations in the steel mill operations.

RATING THE MACHINABILITY OF BULLET CORE STEEL

By NELSON G. MEAGLEY

Chief Metallurgist, Toledo Bullet Core Plant, Willys-Overland Motors, Inc.

MACHINABILITY of the relatively hard steels used in the manufacture of many ordnance items becomes very important. For example, in making armor-piercing bullet cores a steel of the nature of a toolsteel is cut on automatic screw machines at fast cycles and to close tolerances. They are made by the million and the grinding of cutting tools, repair of equipment, supply of high speed steel, and inspection for defective cores become a large part of the operation problems.

For the control of this steel, the metallurgical department of the Toledo Bullet Core Plant (an Ordnance Department, Army Service Forces Plant, operated by Willys-Overland Motors, Inc.) has made an extensive investigation into a practical rating of machinability. It was felt that microstructure alone would not supply the answer. The steel is very similar to an alloy chisel and punch steel, containing much excess carbide. To improve machinability it is cold drawn following a spheroidizing anneal, therefore the microstructure will show the condition of the anneal but will not measure the cold drawing and straightening practice — both of which are as important as the anneal itself.

Reasoning that machining is a physical process and is directly related to the physical nature of the material being cut, it seemed that physical methods should be used to determine machinability, and that chemistry and microstructure are important only in their effect on these physical properties. While the work was done for a special steel for a special wartime part, it is believed that the method has sufficient generality to be applied to other peacetime items in mass production.

The basis of the work are formulas published by E. J. Janitzky in *Transactions* for 1938 (page 1122). These formulas have been altered to measure machinability directly and to take into account cold drawn conditions, thus:

$$M.I. = \frac{10^8}{\left(\frac{2T}{1000}\right)^{1.63} \times R^{1.01}}$$

where M.I. is the machinability index, T is the tensile strength in pounds per square inch, and R is the reduction of area in per cent.

This version of the formula is to be used with caution when the elongation falls outside the range of 15 to 18%, the ordinary range for the metal used in our work. The original bar size is 0.453 in. ± 0.002. For test purposes this is turned down for 2.5 in. to 0.440 in. to localize the fracture, and elongation is taken on 2-in. gage.

The bullet core is turned to correct diameter and shape of point. Machining is to average commercial finish. After hardening, several thousandths are removed from the cylindrical diam-

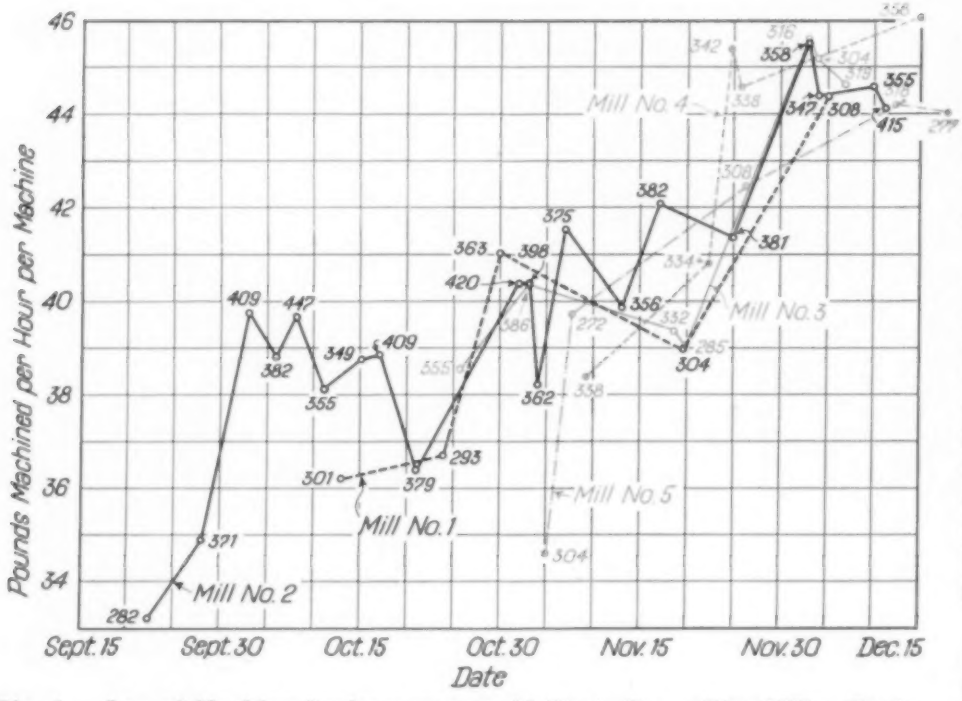


Fig. 1 — Log of Machine Performance on 44 Heats From Five Mills. Feeds and speeds were constant, general shop efficiency was increasing. Numbers represent "machinability index" computed from tensile tests on each heat

eter by centerless grinding. An oil of 95 viscosity (Saybolt universal test in seconds) containing 1.1% sulphur and 2% lard is used for cutting. Dove-tail form tools of either tungsten or molybdenum high speed steel are used and the normal chip is tightly curled. There is no drilling operation required. Speeds and feeds are constant and cannot be changed to take care of material of poor machinability. The cycle time is approximately 6 sec. per core.

The actual machinability of a heat is measured by statistical methods after it has been completely consumed. A record is kept of the pounds machined per hour (pph.) The variation of machine time from normal represents down-time for tool changes, adjustments, and general trouble. A difference of 1 or 2% in pph. may mean a 100% increase in tool grinding, or a 200% increase in inspection resulting from off-dimension cores. It has been found that a statistical treatment of the data for many heats gives a qualitative evaluation of the steel from the several mills.

The machinability index, as determined by tensile testing as above indicated, has been found to give a good indication of the pph. as computed by results of actual machining. Data from 44 consecutive heats of steel from six mills were taken to investigate this relationship.

Six bars, randomly selected from each heat, were pulled and the average taken as the representative physical properties. The M.I. for the heat was calculated from these data. Statistical methods were relied upon to distribute errors uniformly. Since completion of this investigation (December, 1942), a monthly check has been made of this relationship, and the conclusions are the same in each case.

In Fig. 1 all heats from the five mills supply-

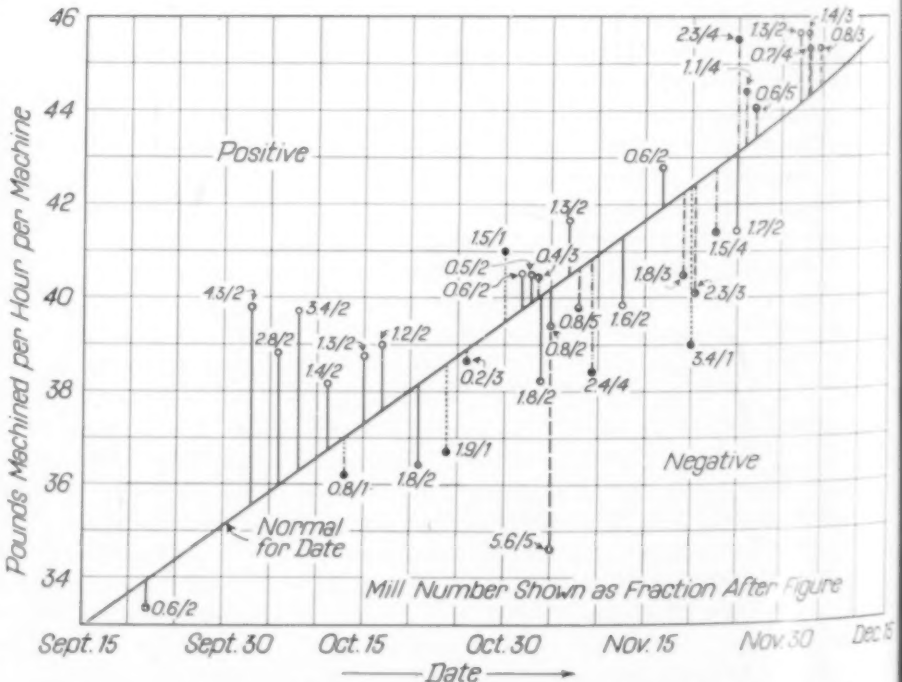


Fig. 2 — Improved Efficiency of Shop Is Approximated by Inclined Line and Variation of Each Heat From This Norm Is Shown

ing the Toledo Bullet Core Plant are plotted according to the date they were machined as abscissa and pounds machined per hour per machine (pph.) as the ordinate. At each point is placed the calculated M.I. It will be noted that for each rise or fall in pph. there is almost always a corresponding rise or fall in M.I. Over the course of this investigation the plant expanded its production, new machines were added, and new operators were becoming more proficient in their work. A steady increase in the efficiency therefore took place. In spite of these many variables other than the machinability of the steel, the M.I. was able

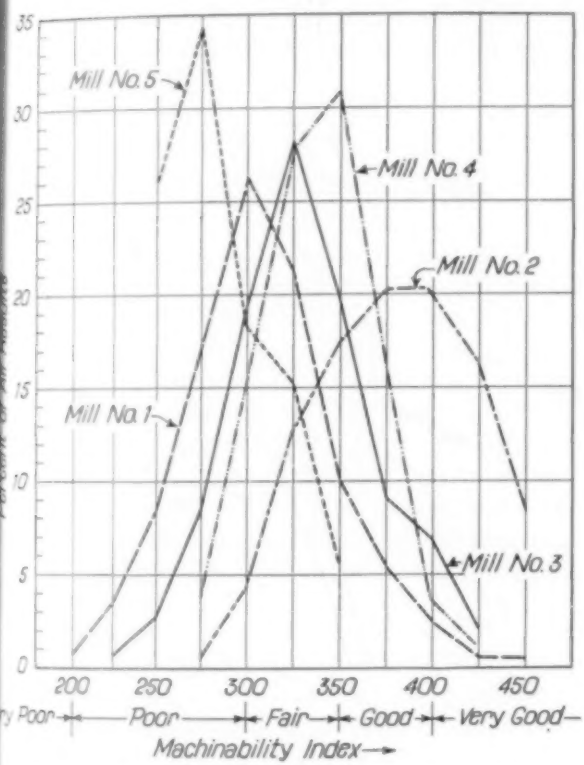


Fig. 3 — Frequency Distribution of Steels of Calculated Machinability for Each Supplier

to predict the relative time required to machine a new heat, in relation to the previous time required for a previous heat from the same mill.

In Fig. 2 the heats have been replotted as in Fig. 1 and a line called the "normal for date" has been drawn to approximate the production to be expected from the general shop efficiency at the time. This line is shown straight although the efficiency did not rise so smoothly and uninterruptedly. It is useful, however, to give a comparison so as to reduce the influence of the variables other than actual machinability of the metal. It is obvious how the heats may be rated according to their position above or below this norm; those above are positive and those below the line are negative. The sum of the negative ratings was subtracted from the sum of the positive ratings to give the average for all mills. The same procedure, taking each mill separately, gives the relationship of this mill to the average:

Average:	1.5 Negative
Mill No. 2	10.4 positive
Mill No. 4	0.2 positive
Mill No. 3	1.7 negative
Mill No. 1	4.6 negative
Mill No. 5	5.8 negative

A frequency distribution curve has been drawn in Fig. 3 for the M.I.'s calculated from the tensile tests. On this chart the M.I. has been plotted as abscissa and the percentage of total readings falling within a 25-point range has been plotted as ordinate. The "average" (taken as the peak of the curve) is given below:

Mill	M.I.
No. 2	387
No. 4	350
No. 3	325
No. 1	300
No. 5	275

It will be noted that the relative position of the various mills is the same in Fig. 3 as in the averages drawn from Fig. 2, where actual machinability is used for rating. In other words, actual machinability and calculated rating puts the product of each mill in its correct relative position.

Figure 4 (p. 70) summarizes the relationship between the M.I. and the actual machinability. This work is of a statistical nature and the points are mathematically determined by a system of grouping in order to reduce variables other than the machinability of the material, as follows: Heats having an average M.I. between 270 and 280 were weighed according to the machine shop efficiency existing at the time and plotted in the center of this division of the abscissa. The percentage relationship to the normal efficiency was plotted as ordinate. This same procedure was used for all M.I. ranges.

A second grouping has been made to further eliminate variables: Three consecutive M.I. points have been averaged and the efficiency plotted in the center of this range. For the next point on the graph, one group was added from right and one group dropped from the left, and so on throughout the abscissa. By this method all variables other than machinability of the material were averaged over and a smooth curve obtained. This line has been shown as straight on the graph, although there are indications of logarithmic properties. It is felt that insufficient tests have been made to determine the exact form.

Microstructure and Machinability

Typical microstructures of the steel we were furnished during the latter part of 1942 are shown in Fig. 5. These are taken at 1000 diameters and etched in 2% nital. Although the specification required 70% minimum spheroidization, the steel is generally much more spheroidized than this — the usual practice being to anneal to 90 to 95%.

The relationship between microstructure and machinability has been rather difficult to determine, because the physical properties are altered by the cold drawing practice. These effects (work-hardening of the ferrite) are not shown in the microstructure. There is, however, an excellent relationship between machinability and microstructure providing the steel is from the same maker and the same mill. It has been our experience that this steel should be annealed to the maximum softness which produces large carbides. The cold drawing should then be sufficient to embrittle the steel and produce an elongation in the tensile test to 15 to 18%. If this is done the M.I. will indicate the condition both of the anneal and the drawing practice.

All other things being equal, the coarser the structure the lower the tensile strength.

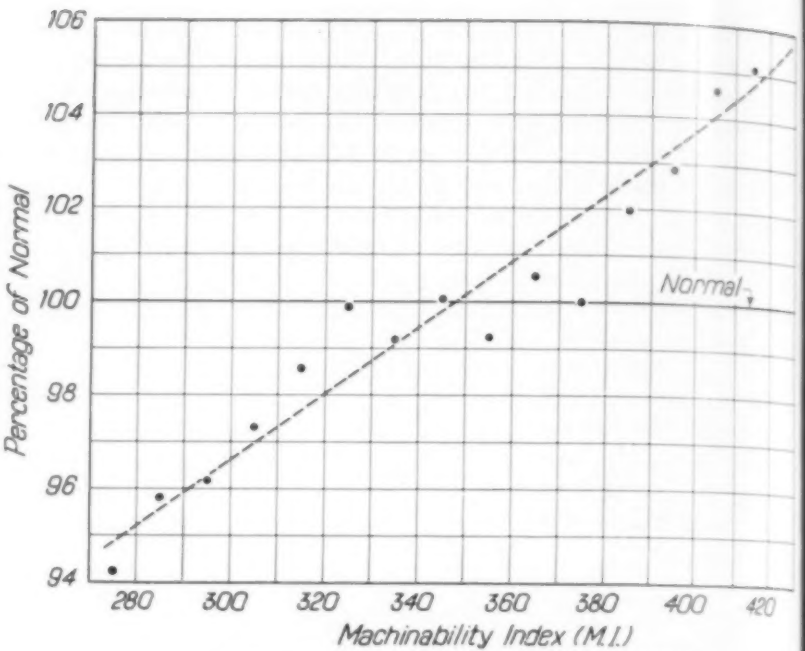


Fig. 4 — Comparison of Average Machinability as Computed (Points) With Creeping Averages for Three Adjacent Points (Dotted Line, Approximate)

Mill Practice and Machinability

Mill practice has been found to have a decided effect on the physical properties, and therefore on the machinability index. In addition to the anneal, the uniformity of the hot rod, the cold drawing draft, and the straightening speeds all have their effect. To verify our findings in this regard, several mills have cooperated by supplying test specimens representative of various practices, and this phase of the work is now being carried on.

The cold draft, through work and strain

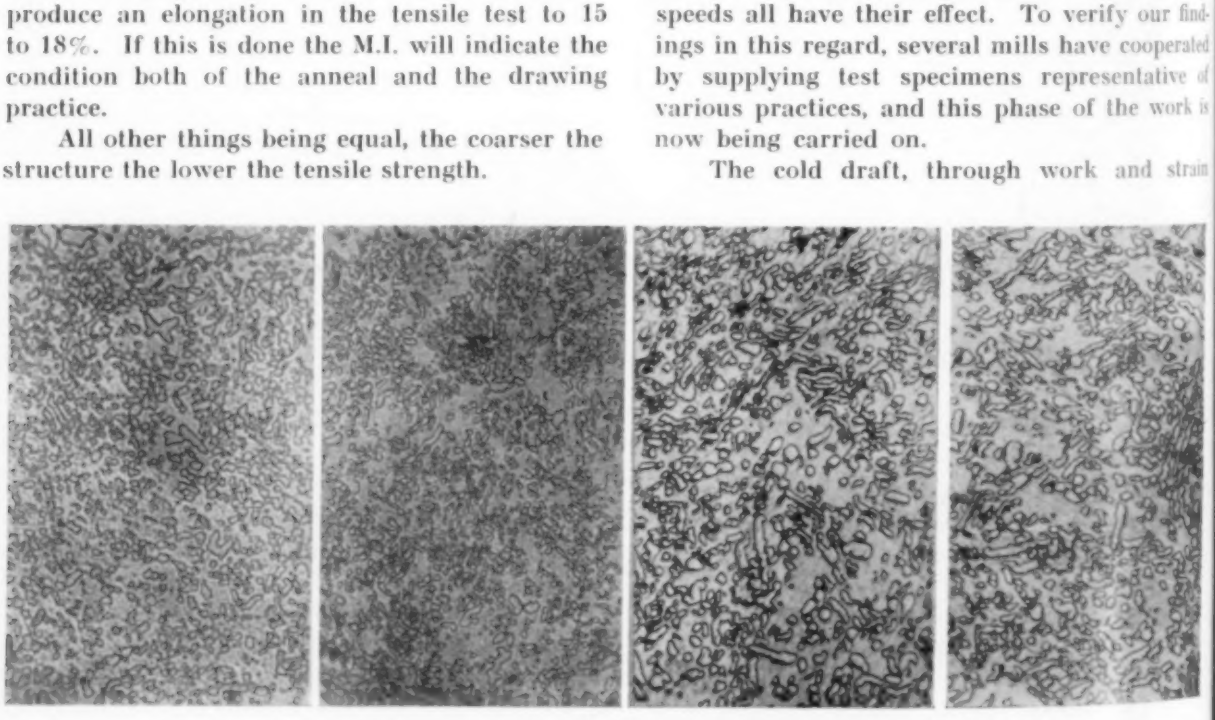


Fig. 5 — Representative Variations in Carbide Size and Distribution in Commercial Deliveries of Bullet Core Steel

hardening, increases the tensile and yield strength, and reduces elongation and reduction of area, and it is for this reason that our formula must be used with caution when the elongation is outside the range of 15 to 18%.

Wide variation in the hot rod size causes a change in draft and result is a lack of uniformity. The release of strains through straightening is also extremely critical, and alters the physicals greatly when different speeds are used.

When the data are more complete on these points it is the intention to publish our findings.

Conclusions

Machinability of a material varies directly as a function of the brittleness of that material and inversely as a function of the strength. The M.I. formula has been shown to be a practical method for measuring these variables when machining a high carbon, alloy steel.

The formula cannot be taken as a representation of the whole picture as there are other variables in machinability besides strength and brittleness. Some are *(a)* the desired finish on the product, *(b)* problems resulting from types of chips, *(c)* decarburization, producing a tough surface, *(d)* welding tendency of chips on the tool, *(e)* type of cutting oil, and *(f)* variables in cutting tools.

The M.I. (calculated machinability index) is a measurement of the resistance of the material to the shearing action of the tool. By its use it has been possible to find a good relationship between machinability and the tensile properties. The other variables listed above either do not exist in our production, or are reasonably uniform throughout all heats.

The author wishes to express his appreciation to Harold Yarian, under whose direction the tests were made and who made many valuable contributions to the investigation.

THE FUTURE AUTOMOBILE

IN A TALK on "The Social and Economic Responsibility of the Automobile Engineer", published in the May 1943 issue of *The Journal* of the British Institution of Automobile Engineers, Donald H. Smith avers that engineering developments practically stopped in 1935 in the field of private motor cars. Since then the engineer has been dominated by the salesman, the publicity expert and the production specialist, and all too frequently "that which the engineer-designer knew to be sound could be, and often was, overridden by one or all of the others. . . . ." Particularly, he says, has development stagnated in the English motorcycle.

"Many of the errors of industrial life in the recent past are now admitted," continues Mr. Smith. "It is realized that the somewhat cynical abandonment of sound principles, coupling therewith a prodigal wastage of material and labor on production of ephemeral value, has had astonishing repercussions. May it not be profitable, therefore, to look to the future and to endeavor to avoid being involved once again in the currents of the same stream?

"Although manufacturing facilities will be greatly increased, material supplies may be short and unbalanced for many years. It will be wise, therefore, to conserve material by avoiding designs laid out solely to facilitate cheap and rapid production in the interest of high pressure sales. In short, to abandon the system of scrapping and replacing after a short life in favor of building to last a reasonable time on lines that facilitate repair work. The general inhibition of rust, either by metal spraying or other means, of all the under-parts of road vehicles would have been of more service to owners today than any of those innovations of external appearance and unnecessary embellishment that were hailed so joyously when they were introduced.

"The anticipated influence of aircraft design upon the future car is a popular subject with the prophets. However, the aircraft engine runs under conditions that preclude its ordinarily developing anything like the same kind of power characteristics that are required of road vehicle engines. Indeed, its service is so specialized that the application of its design features is either undesirable or remote or both.

"The use of light alloys is also suggested for the road vehicle and to some degree the future may see many developments, particularly in body construction on aircraft lines. But the technique of light alloy usage is difficult and costly. Light alloys are by no means *(Continued on page 132)*

Transparent replicas of etched metal surfaces, necessary for work with the electron microscope, are also quite valuable in ordinary optical microscopy for visual examination and permanent records of microstructures that may be destroyed by further experimentation and, if the plastic is previously dyed, may serve to measure the relief in the etched surface.

SURFACE REPLICAS CONTAINING DYE FOR USE IN THE LIGHT MICROSCOPE

By VINCENT J. SCHAEFER

Research Laboratory, General Electric Co., Schenectady, N. Y.

MORE THAN fifty years ago J. B. Haycraft proposed in the *Proceedings* of the Royal Society (1891) the use of transparent replicas of soft collodion for the microscopic study of surfaces. In 1924, L. V. Foster published the results he obtained in *Transactions* of the American Society for Steel Treating using a light microscope with collodion replicas of etched metal surfaces, and showed the various types of lighting which could be used to bring out various characteristics of the surface configurations. Despite the excellent results obtained the replica method for studying surfaces was not extensively used — primarily, perhaps, because it did not supply any appreciable amount of new information to the metallurgist, coupled with the somewhat complicated technique recommended.

Within the past few years the use of replicas has assumed considerable importance with the application of the electron microscope to the study of metallurgical problems. A number of techniques have been proposed for preparing replicas thin enough to permit the transmission of electrons, and strong enough to withstand the handling necessary in preparing and mounting the specimen in the electron microscope. Details may be found in *Journal of Applied Physics*, 1941, p. 692; 1942, p. 427; 1943, p. 23.

In recent notes (*Physical Review*, 1942, p. 495, and *Science*, 1943, p. 188) the present writer proposed several new methods for removing thin resin replicas from the surface of metals and other objects, including a method designed primarily for the light microscope. Briefly, it consists in the formation of a transparent layer of polyvinyl formal resin, by flowing a dilute solution of it on the surface of the specimen to be studied. After the solvent evaporates a piece of transparent cellulose scotch tape is pressed into optical contact with the replica and peeled away from the specimen. The replica sticks to the tape and is then placed on a glass slide and observed or photographed in the light microscope using transmitted light. The entire operation can be carried out in a couple of minutes and work with the electron microscope has indicated that the surface structure shown by a polyvinyl formal resin replica is faithfully reproduced to better than one-fiftieth of a micron (a small fraction of the wave length of light).

In the present paper I would like to describe a new application for replicas in the study of surfaces. By this method the relative *depths* of adjacent regions may be seen at a glance, recorded on the photomicrograph, and even measured with a considerable degree of accuracy.

For example, an etched surface of pure copper, seen by vertical illumination in the metallographic microscope, looks like Fig. 1. With such a sample it is impossible to determine the

relative depths of different areas in the field without making numerous optical measurements of them. This is due, of course, to the equal amounts of light reflected from those portions of the field

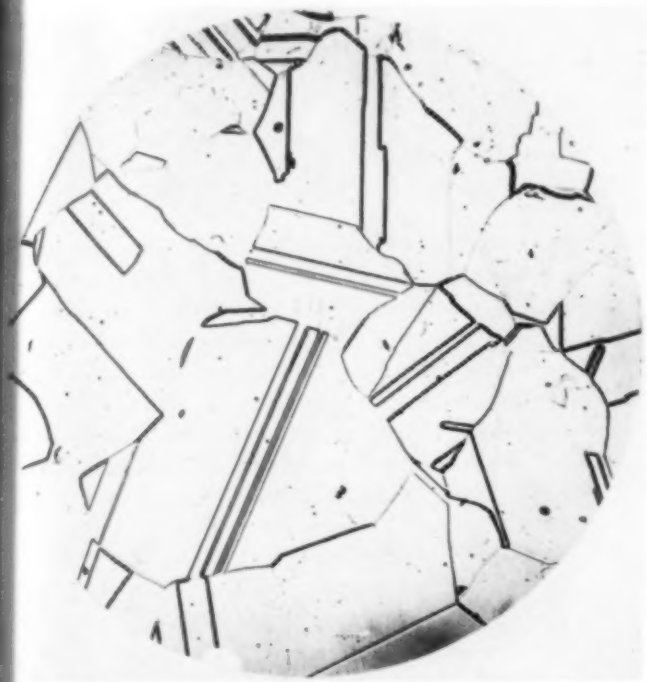


Fig. 1 — Copper Surface, Polished and Deeply Etched With Potassium Dichromate, Photographed Under Vertical Illumination at 100 Diameters Magnification and Reproduced at 50 Diameters

at right angles to the optical axis of the microscope.

A replica of the same region prepared in the manner to be described looks like Fig. 2, when illuminated by transmitted light. In this photomicrograph the several degrees of density are directly related to the relative depths of the several grains, the darkest regions being the lowest levels while the lightest parts show the portions least attacked by the etching solution. This effect is obtained by dissolving a dye in the resin solution used for making the replica. Since the under surface of the replica follows the configuration of the etched sample while, as the solvent evaporates, the upper surface remains flat due to surface tension forces, the part of the replica covering a region of deep etch contains more dye per unit area than a shallower region nearby. This difference in thickness produces the variation in light transmission seen in Fig. 2.

In making a replica the solution is flowed over the surface, the excess drained for a few seconds and the solvent permitted to evaporate over a period of a minute or two with the surface held in a horizontal position and covered with a petrie dish to retard evaporation. The concentration of dye and resin material must be suited to the particular specimen under study, since the degree of etch and relative depth of various portions of the surface often vary over a wide range. Since a completed replica may be prepared in less than 5 min., I have found it convenient to have several stock solutions which can be diluted if necessary. Those found most useful include a 3% and a 1% resin solution, each containing 0.75% by weight of an oil-soluble dye. The dye which I have found to be quite satisfactory is ethyl violet. Used in a combination with a Wratten B No. 58 green filter in front of the light source, excellent contrast is obtainable for visual observation or with panchromatic film. Both dye and resin are dissolved in ethylene dichloride or dioxane. (A subsequent paper is planned which will furnish specific information on the relation between concentration of resin and dye as a function of thickness and density, as well as the relation of density to relative depth in a specific sample.)

As an aid in removing the replica it is sometimes necessary to apply a slight amount of moist

Fig. 2 — Dyed Formvar Replica of Same Area as Fig. 1, Photographed With Transmitted Light. (All photographs made by Mrs. Constance Brodie)

warm air, such as from the breath, to the top surface of the replica just before applying the scotch tape.

At present, available transparent scotch tape is not of good optical quality and sometimes produces artifacts such as the faint parallel out-of-focus lines shown in Fig. 3. Where it is desirable to have the replica free of the scotch tape coating, a small triangular hole is cut into the tape before applying it to the replica. This hole is then located over the region to be studied, the tape pressed into contact with the top surface

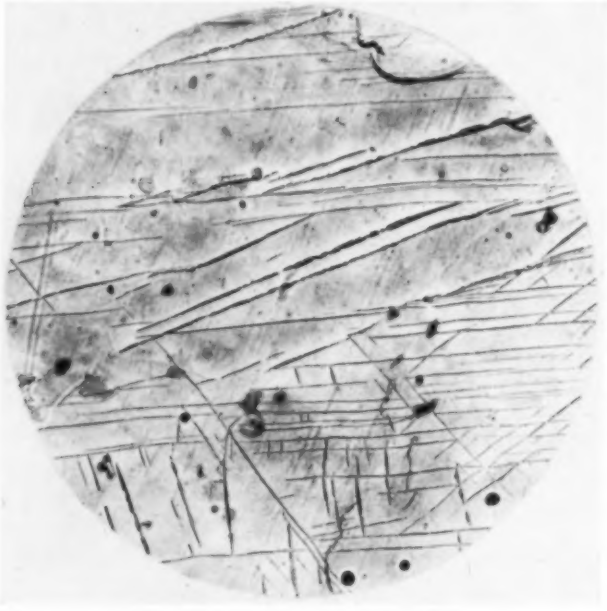


Fig. 3 — Photomicrograph at 100 Diameters of Dyed Formvar Replica of Electrolytic Iron Showing Neumann Bands. Etched in 2% nital. Parallel, out-of-focus markings originate in the cellulose tape backing

of the replica and the replica removed in the usual manner.

Since a complete impression of the specimen and the mounting material is obtained by the cellophane method, including reference marks in or adjoining the specimen, it is a simple matter to find by measurement identical regions in both the original and replica specimens for optical comparison. Another advantage in making the replica of a surface is the fact that a record of the entire specimen is obtained, parts of which can be used later for reference and photomicrography, if the original specimen is altered by experimental treatment. This avoids an extensive series of photomicrographs, prior to subsequent experiments, on the chance that some unknown detail must be available for later study, after its existence has been destroyed.

RECLAMATION OF FIRED CARTRIDGES*

By John Rae, Jr.

VARIOUS TROUBLES have been associated with the use of scrap fired cartridge cases, and they have generally been avoided by manufacturers, except for a low-grade product, so their influence was investigated on the properties of straight brasses containing 62, 59, and 56% copper, three leaded brasses, and one naval brass.

The heats were melted in half-ton low frequency electric induction furnaces and poured into 6¾-in. water-cooled molds, and the billets extruded. Mixtures were made in which cartridge cases replaced copper and zinc as far as possible, and comparative heats were made without cartridge cases. In some experiments a calculated amount of antimony was added to a melt made up from virgin metals.

In the extrusion alloys made of straight brasses, a marked difference in color was noticed between fractures of the alloys made from cartridge case mixtures and those made from normal mixtures. The effect was less pronounced in the leaded brasses. Cases which had been "clean fired" and "muffled" were both used, but their effect was the same.

Among the physical tests, except in the case of the higher copper alloy in which the elongation is slightly reduced, the main impairment of properties is in the Izod and bend tests, and, in one alloy, in the cold riveting test. Naval brasses were unaffected by the change in the mixtures.

The effect of antimony up to 0.012% on the physical properties of 62:38 brass was studied in the chill-cast samples and in extruded rods. It had a similar effect on the properties of drawn rods and of as-extruded material, the impairment being practically confined to the Izod value and the angle of bend. The effect of the light draw is to raise the Izod values slightly in both mixtures A, made of virgin metal, *(Cont. on p. 124)*

*Abstracted from "The Use of Fired Small-Arms Cartridge Cases in the Production of Some Alpha-Beta Extrusion Brasses: Indications of the Effects on the Physical Properties of the Extruded Rods", *Journal* of the Institute of Metals, Vol. 68, 1942, page 311.

Portions of an address given at Columbia University upon receipt of the Chandler Medal "for his dynamic and successful leadership in the American chemical industry. In addition to founding a chemical industry which depended upon Michigan salt brines, his daring enterprise in the direction of the extraction of bromine and of magnesium from sea water, the production of synthetic plastics and synthetic rubber has attracted world-wide attention."

REDISCOVER THE RAINBOW

By WILLARD H. DOW

President, Dow Chemical Co., Midland, Mich.

THROUGH countless centuries our forbears marvelled at the beauty and glory of the rainbow; the ancients often worshipped it as a manifest from Heaven. But the ancients, like so many in recent times, could not conceive of a Deity as other than a mere provider to man's material wants. They conjured up a pot of gold at the rainbow's end. In their simple and artless thinking they envisioned a real pot of real gold and thus a means to wealth and happiness.

The ancients were right in holding that the rainbow held a promise. They were wrong about the promise being in a pot that one could lift and carry away. The rainbow, as scientists were to discover, is a revelation of the spectrum and an invitation to man to find out how to use it to investigate nature's laws and to unlock treasures so vast that they could not be counted in pots of gold; for no one can evaluate in money what the spectroscope has done for science and humanity.

The rainbow is not nature's way of pointing out a shortcut to wealth. It is nature's way of indicating how we might better work for the wealth which nature has in store for us but will not give us merely for the asking. At that, I doubt if as much blood and sweat and tears went into the development of the spectroscope as went into the forays to find the pot of gold at the end of the rainbow. Fortunately, there are no statistics on the subject.

I have asked you to chase the rainbow with me, not so much out of love for the chase but for the revelation of scientific precepts that will contribute to the betterment of all peoples. We are in the midst of a holocaust of destruction in which apparently nothing is sacred or inviolate. The war, if it demonstrates anything, demonstrates that mankind as a whole is morally and politically unfit to apply the knowledge which science has placed at its command. Are we not today applying against mankind nearly all the forces and laws of nature which science has uncovered for the making of a better and happier living?

Regardless of what fine, resounding words may be used as introductions, every scheme to divert the working of natural laws from constructive and useful purposes to destructive and useless purposes must lead to sorrow. Is it not odd that there should be so many coming forward now with plans for perfect world orders to be built out of the ashes of the present debacle? Those who offer the plans are much the same people who achieved the failures. And so I suggest to you as men of science that our greatest contribution may be in the devising of ways and means to inject something of the truly scientific approach in the future world in order that we may have at least a nation, and perhaps a world, in which the laws of nature may be allowed to work and man will be able to avail himself of his countless opportunities.

The first requirement of any plan is to test it carefully to determine if it conforms with natural laws. For planning without this exact knowledge, or planning without any knowledge, may easily be planning against nature. The Tower of Babel, it may be recalled, was part of

a plan to penetrate to Heaven — although I am not informed as to what the planners were going to do when they got there. It was magnificently conceived, but it ended in rubble and confusion.

There is an omnipotent plan. I am not going to discourse on any theological abstraction such as predestination. I simply mean to point out that we of the scientific mind have already learned there are countless natural basic laws and that many of them are difficult to uncover and to interpret but that, once understood, their application is simple. For instance, the law of gravitation is never questioned, yet it was not understood for many centuries. The declaration that "there is an omnipotent plan" signifies in its simplest terms that natural laws control every activity. So long as our actions conform to these natural laws, we cannot help but succeed in our purpose.

Is there a scientist who does not appreciate the concept of an omnipotent plan? Each synthesis, each reaction and all processing, the scientist watches with keen appreciation, hoping to discover some new phenomena. Our lives and all we direct are successful only in so far as we can properly interpret the magnificent plan.

It is not without significance that the capable scientists of today tend to be devoutly religious; whereas many of those who claimed to be scientists only a generation or two ago took pride in proclaiming themselves as agnostics or atheists, for they could not correlate religion and science. We of today are so much better informed than our fellows of generations ago that we have enough perspective to recognize our own insignificance. . . . .

Laymen have been trained to think that the physicist or the chemist dives into nature, so to speak, and comes up with something wonderful. That, of course, is not true. The best we can do — indeed the only thing that is worth doing — is, with infinite patience, to work out the laws of nature as they apply to this or that tiny section of matter and then find a way to direct the working of the natural law into a channel where it may serve mankind. That is why the end of every discovery must eventually be a commercial utility. Not otherwise than in commerce can we find an exchange value so that people may employ the utility.

The idea of one scientific development being a tool which helps in another development is clearly understood and appreciated by those with scientific experience — and but slightly understood by others. The radio is probably considered by the public as one of the most necessary means of entertainment and communication, but the whole physical science of radio is one of the most vitally necessary tools in all sorts of commercial operation. It permits automatic control where human hands cannot reach. The electron microscope in turn permits magnification that lenses cannot produce. It would be an unwise prophet who would attempt to define the probable limitation of electronics, or what it will do in aiding all branches of science to further understanding and benefit.

Another example: The extraction of bromine from ocean water was not a commercial economic process until comparatively a few years ago; and that was only because in earlier days we did not have the equipment with which to make possible the careful and exacting acidity control of the ocean water. In 1934, for the first time in world experience, we found how to handle enormous volumes of ocean water in continuous flow and at the same time control the acidity within narrow limits. That was the real key that opened the first lock of the vast resources of the ocean. Today thousands of tons of bromine are extracted annually from the ocean to the tremendous advantage of the Allies in aviation alone. What body politic a score of years ago could have directed or even wisely suggested the solution to such a problem? What "directive" could have substituted for unfettered imagination, the desire of the human being to show self-expression and to carry on against all kinds of obstacles? The persistent individual, if he follows natural laws, will invariably succeed. The desire for individual expression is a trait of our species and, after many thousand years of records, it might properly be called a natural law of human reaction.

Some say there is no truth in the old-fashioned economic axiom, generally known as the law of supply and demand; but the fact remains that human interest is stimulated when a shortage of anything is imminent. What better examples can be presented than the stories of magnesium and synthetic rubber? The more intricate the problem, the more stimulating the urge to solve it.

Magnesium From Salt

Magnesium is an interesting story and perfectly simple. Perhaps that is the principal reason it is so difficult to understand. Magnesium is found in ample quantities in many localities — always in a combined state such as dolomite limestone, or some other compound such as the magnesium chloride in ocean water and native brines. In most localities where dolomite is found, fuel costs are fairly high or transportation charges constitute a large factor. The problem

therefore, quickly resolves itself into one of determining the relative cost of mining rock or pumping ocean water. We chose the ocean — deciding the volume was large enough to justify the investment. We made our decision and started plans within a few months, as the general method of isolating magnesium from brine had been in operation with us for 25 years.

When we first decided to extract bromine from the ocean, some of us were concerned about the possible contamination of organic matter and its effect on final recovery. This finally proved to be a will-o'-the-wisp, for the organic matter remained aloof. Thus our fears were dissipated.

On the other hand, many precautions were taken in the magnesium-from-sea-water extraction process. When the plant was finally started, we found it necessary to make some radical changes in order to prevent the concentration of boronate from becoming too great in the electrolytic cells. Boron has the property in this electrolysis of being an active agent capable of reducing the yield of magnesium to practically nothing. Thus boron had to be controlled partly by elimination and partly by leaving the iron and manganese, naturally present, to control the boron. Here was an outstanding example of nature's elements in small quantities laying down a definite rule of operation; a control which none of us at that time thoroughly understood.

We have all heard much about the synthetic rubber program.....We have plenty of technical knowledge touching the synthesis of rubber. After the war is over, there will be as many different kinds of synthetic rubber (better termed "elastomers") as there are manufacturing companies. Each product will have its own particular qualifications and will be supplied to tailor-made specifications. Elastomers are here to stay. Much like the history of indigo and many other natural products, the synthesized product will become better than the natural. Uniformity of specifications and lower costs will permanently establish it as a new industry after the war.

In this connection, it is interesting to reflect upon the competition between synthetic and natural products.....That is the way we talk about offering a selection between a man-made uniform product and a nature-grown uncontrolled product. But let me suggest to you that there is no fundamental competition between substances; the competition is between the skilled labor of the factory and the coolie labor of the plantation. May it not be a law of nature that the product which may be turned out by the well paid, well fed, well housed worker must displace the product which requires men to work in the manner and at the wages of a beast of burden?

One so often hears of our economic need for this or that basic raw material. Tin may be taken as an example. Granted that we are all creatures of habit and that we are more or less tied to the tin can for a large portion of the food we eat, why are we not smart enough to develop a substitute? Failing this, what about the possibility of finding a new source of tin? We do not know of the existence of tin in ocean water, but do we need tin? There is probably little reason to upset our economy for the mere need of something like tin. Should we not rather work on a substitute and develop something that is better and thus open new opportunities? There is no reason why we should not sometime eat the containers in which food is stored. We have learned to make synthetic sausage casings and ice cream cones. Why stop there? New synthetics are already available for manufacturing flexible tubes for tooth paste, shaving cream and the like, formerly requiring the metal tin.....

You will hear of wartime developments and accomplishments which otherwise would have taken years to attain. Shall we teach our children that it takes a war emergency to create real advance? Of course not! War emergency is one thing; peace is another. The two are not to be confused. There is no comparison. We also hear of high-placed men preaching that inventions should be curbed for the good of society. They are grotesquely misinformed. To invent is one of the freedoms of America. Every child has been taught to believe he may become an Edison of his day, and why not?

The ultimate changes in this world are infinite and, therefore, beyond human imagination. They are infinite because nature's laws are infinite. The bright spots of progress merely reflect the operation of natural law. Every new milestone of progress is but a period of more basic and clearer understanding, with the aid of the physical and chemical sciences, of the forces of nature and their laws. Finite milestones serve only to define nature. In no way does nature become less infinite. There are always greater possibilities and new horizons ahead of us. Nature attends. We must conform.

A world at peace will be a world fundamentally based on nature's laws. Nature's way is simple, plain and direct, but we sometimes follow a devious path before we reach understanding. Those nations who follow nature's laws most closely are bound to become supreme — supreme in their modesty, supreme in their honesty and humble before nature's altar. Again I ask you, consider the rainbow.

Induction hardening (Tocco process) is ordinarily performed on smooth cylindrical surfaces with alternating electric currents of moderate frequency — about 3000 cycles per sec. Hardening of internal bores, as achieved by Budd Induction Heating Co., required frequencies some three times as great, and current of this nature has permitted the Caterpillar Tractor Co. to harden crown shaved teeth, with practically no distortion, on large spur gears for heavy tractor drives. Strategic alloy is saved and a more durable gear is produced.

CASEHARDENING LARGE GEARS WITH HIGH FREQUENCY CURRENT

By GLEN C. RIEGEL

Chief Metallurgist, Caterpillar Tractor Co., Peoria, Ill.

IN "CRITICAL POINTS", the Editor's department in *Metal Progress* for December 1942, is described the system of metallurgical control of purchases enforced by Caterpillar Tractor Co., and the following conclusion was stated: "An organization grounded in such a metallurgical tradition will have the boldness to convert a 3½% nickel steel gear to a plain carbon steel, even though it involves a three-year development program costing $500,000. Right now, however, this one item is saving 144,000 lb. of scarce nickel every year." The aim of the present article is to describe that major conversion in more detail.

The part is known as the "Final Drive Gear" on our model D-8 tractor. It is an important part, as it is the final link in the chain of power between the engine and the main sprocket that meshes into the track chain. The D-8 tractor itself is a powerful machine, weighing 17½ tons in its peacetime embodiment, and is adaptable to many military uses demanding strength and ruggedness; 113 draw-bar horsepower is transmitted by the gear under consideration.

It is obvious that any change in the final drive gear could not be tolerated if it would imperil the performance of the tractor and the reputation of the builder. Even in wartime, any debasement of quality in such a vital part could not be classed with such changes as, for example, the replacement of a stainless steel drain plug with one of common iron whose corrosion would cause only minor inconvenience and small delay. Gears, shafts, and track links are subjected to unpredictably high and sudden peak loads, and demand steels capable of resisting sudden failure.

Failure of such parts, if made of a substitute, would seldom be in the nature of more rapid wear and consequent lessened life, but almost always would consist of sudden breakage of the machine element, tying up of vital equipment, much loss of time and a very considerable replacement expense. To permit such a sacrifice of the quality would be a distinct dis-service to those whose operations, and even lives, are dependent on the successful performance of those machines.

Now to return to the specific problem:

When the D-8 tractor was designed, our engineers realized from previous experience that a final drive gear of the size required for this, our largest tractor, could not be produced by any known method of hardening sufficiently free from distortion to give good tooth bearing. In carburizing, or directly hardening large gears of alloy steel, we invariably obtain the "hour-glass", "barrel-shaped", or "leaning-tower" effect in the teeth. This naturally produces a concentrated bearing on one end or the other, resulting in pit-

ing and fatigue fracturing of teeth, the usual causes of premature gear failures.

To correct the poor bearing, resulting from distortion in heat treatment (prior to hardening by electrical induction), we left sufficient stock on the teeth to finish the tooth form by Fellows shaping. This required special machines and was very tedious because of the final hardness of the alloy gear, which was necessarily a compromise in hardness and required some sacrifice in wear resistance of the gear.

The gear, as shown in the illustrations, is a large one, 25.7-in. pitch diameter, 5-in. face, cut with involute teeth of 0.514-in. chordal thickness. In its original embodiment it started as a 350-lb. billet of S.A.E. 2345 steel (3½% nickel), which was upset and rolled by Edgewater Steel Co. in machinery suitable for making rolled car wheels. This rough forging was normalized by heating 3 hr. at 1550° F. to 187 to 217 Brinell hardness, and was then ready for rough machining for control dimensions and oversize tooth form.

The hardness — a compromise, as has been said, between machinability and wear resistance — was achieved by an oil quench from 1440° F. (heating was done in an atmosphere furnace to avoid scale), followed by a tempering that brought the Brinell hardness down to the range of 363 to 415 (approximately Rockwell C-40). After this treatment the teeth were finished on a Fellows shaper, the bore sized, and the bolt holes drilled and reamed to register a dowel fit.

It will be observed that this practice had little that is new to those who favor oil quenched (through hardened) gears rather than carburized (surface hardened) gears. From a production standpoint there were two major things wrong with it: In the first place it used large quantities of expensive steel; annual production even in peacetimes would consume nearly 100 tons of alloying nickel in these parts. In the second place, accurate gear cutting at a hardness level of 400 Brinell was not only a slow process with large and costly machinery, but the cutters would stand only four gears per grind.

Even more disturbing was the fact that these expensive gears were not good enough. They would rapidly wear in heavy service, and the correct involute contour was soon destroyed. On a gear testing machine, pits would appear at the pitch line after 100 hr. at full load. Since pits are an evidence of fatigue failure, it was apparent that the gear teeth were not strong enough at their working surfaces. Strength could not be increased, however, without increasing the hardness, and the hardness was already at the machinable limit. An alternative, of course, was to raise the hardness and grind the teeth to final contour, but this was rejected on account of the excessive cost of the required machinery and its operation.

Management of the Caterpillar Tractor Co. had decided by 1939 that something drastic had to be done to improve the life of this vital part. The metallurgical department realized that the problem could be solved if a higher surface hardness could be given the finished teeth. A change

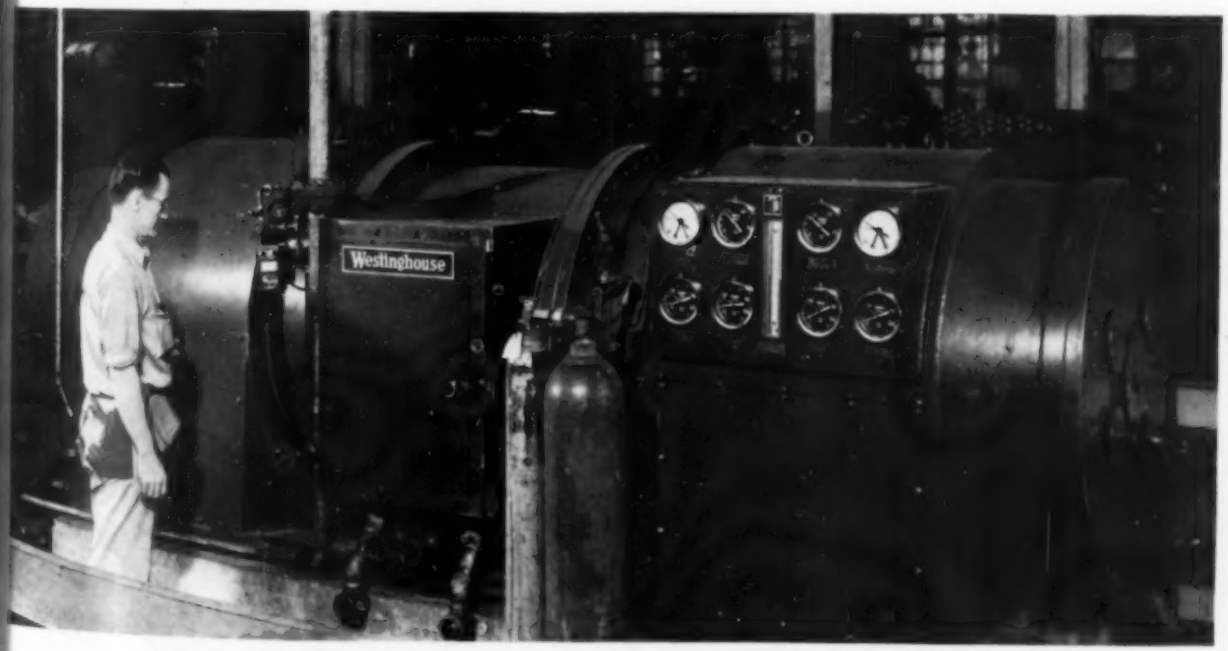


Fig. 1 — 800-Hp. Motor and 500-Kw. Alternator (Both Totally Enclosed and Hydrogen Cooled) for Generating Current at 9600 Cycles per Sec.

to a carburized gear was indicated, but experience, backed up by some supplementary tests, indicated that this particular gear would likely distort so much during the carburizing cycle that it could not be straightened out satisfactorily in the quenching fixture, and that subsequent grinding (almost a prohibitive operation from a cost standpoint) would cut away a lot of the case on one tooth and a little on another, and the resulting irregularities in case depth would show up later in erratic performance in service.

The alternative was to select a steel which had sufficient strength and toughness in a stress relieved and machinable condition, machine such a forging accurately, then harden the surface of the teeth by inductive heat (Tocco process). We had little doubt that a suitable steel could be provided; we had more misgivings about various details of the heat treatment.

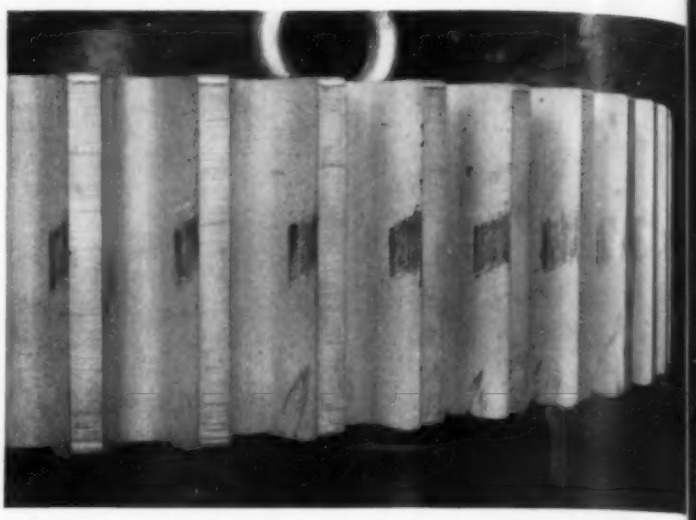


Fig. 2 — Crowned Gear Run Against a Master Pinion and "Blued" at Tooth-to-Tooth Contacts, Thus Proving Central Bearing. About two-fifths natural size

In adopting changes in design and especially changes in materials used in its products, Caterpillar Tractor Co. has been in a most favorable position by reason of a company policy long pursued. This was a program of avoiding the difficulties that might arise from dependency on a single source of supply, except in cases where that was unavoidable. Even where a single vendor's price, quality, capacity and service were wholly satisfactory, a second source of supply has been developed and maintained as an extra measure of protection. To that extent "Caterpillar" may be said to have anticipated some of the difficulties arising from a war emergency. Many studies of alternative materials, however, have been prompted by a continuing desire to build better products — when possible, at a lower price. This has turned us to steels of various compositions, subjected to various methods of heat treatment. Intensive studies in that direction were started more than a decade ago. Between that time and the present, sample parts made from alternative materials have been tested in machines subjected to many thousands of hours of regular and severe work in the field.

Fig. 3 — Preheated Gear Is Indexed on Table (in Raised Position) so Teeth Will Register With Quenching Ports. Duplicate fixture and much other equipment for induction hardening furnished by Ohio Crankshaft Co.

Such studies have convinced us that it is far better to know what service any machine part must withstand, and provide material that will perform that service, than to assume that only a material of a given chemical composition will be satisfactory. In other words, we long ago adopted the plan of grad-

g each heat of steel by its physical properties, y doing this within the 48-hr. period required r pit cooling a high grade billet, and giving the ill a prompt "go-ahead" or "divert" signal.

Likewise we had ample and satisfactory perience with induction heat for surface hard- ing. As early as 1938 a machine for hardening ack pins was installed; now, 16 complete induc- on hardening units are scattered through the oduction lines. With their help heavy shafts, awbar pins, push rods, accessory and other afts, formerly made of alloy steel, are now ade of carbon steel. We were fairly sure that plain carbon, fine grained steel, containing out 0.45% carbon, would carry the loads, would tough enough to stand the impacts, and could hardened satisfactorily. Such studies as those utlined by Messrs. Vaughn, Farlow and Meyer Caterpillar Tractor Co.'s metallurgical staff in the paper entitled "Metallurgical Control of Induction Hardening" presented to the 1941 Convention, proved that alloying elements such s nickel and chromium were wholly unnecessary or a maximum surface hardness — a matter which is primarily related to the carbon content. *Depth* of hardening, of course, is increased by the presence of alloys, but gear teeth require superficial hardening only — say, a hardness of C-50 or more for a depth of 0.125 to 0.150 in. Our experience indicated that this can be achieved by induction heat; the heating cycle is so short that there is little or no time for undesirable grain growth or for surface oxidation.

However, all our equipment was designed for rather small parts of cylindrical contour. The various machines operated at the more-or-less standard frequency of 9000 cycles per second. We felt that considerably higher frequency would be needed to produce a reasonable thickness of hardened metal at the root of the tooth. In other words, the higher the frequency the closer the induced currents hug the surface, following any irregular contours.

Fortunately at about that same time Budd Induction Heating Co. of Detroit was engaged in an interesting development wherein the *bore* of a wheel hub was being heated by an inside inductor rather than its outer surface by a surrounding inductor, and which required to a striking degree the surface effect we were seeking. For that purpose Westinghouse had built electrical equipment rated at 500 kw., 800 volts, 9600 cycles, and through the cooperation of H. E. Somes, chief engineer, we were able to use this power plant long enough to convince ourselves that 9600-cycle current would give a sufficiently uniform heat effect along the tooth faces.

Heavy Electrical Equipment Needed

After these successful experiments a duplicate equipment was ordered for our Peoria plant. It consists of an 800-hp. motor, direct connected to a high frequency inductor generator, both hydrogen cooled to reduce size and improve efficiency. (See Fig. 1.) It runs at 3600 rpm., such high speed being about the safe limit for the centrifugal forces generated in a rotor of required size. Four banks of capacitors are installed alongside to improve the power factor, and clever control equipment, housed in a steel cabinet, insures an automatic regulation of current at all times during the heating cycle by adjusting the current in three steps as the metal in the gear's surface

Fig. 4 — After Heating Cycle, the Gear Is Again Indexed, the Table Lowered Into the Quenching Fixture, and Sides of Teeth Are Hit by Individual Sprays of 10-Lb. Water. View shows the very beginning of the quench. After quenching, the table is raised to loading position and hardened gear removed to tempering furnace

passes through the transformation range and loses its magnetism. Electrical details are out of place here; interested readers may refer to the article by Mr. Somes and discussion by C. E. Levy of Westinghouse Electric & Mfg. Co. in *Iron & Steel Engineer* for July 1941, page 39.

It would be tedious to relate all the trials we made to secure the best combination of operations. Briefly, the routine of production of the final drive gear is as follows:

The billet of S.A.E. 1045 steel (no alloy), after pasing metallurgical inspection, is upset and rolled into a ring forging as before, normalized

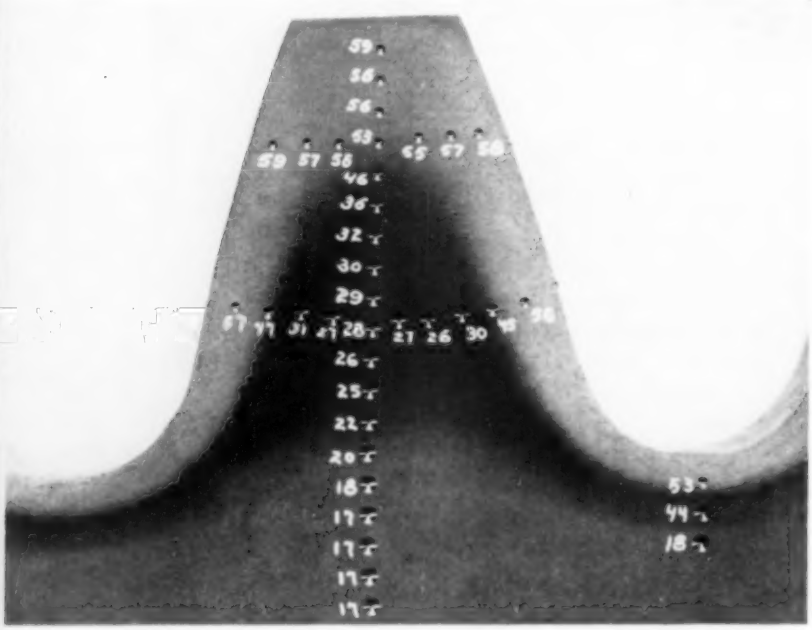


Fig. 5 — Hardness Survey (Rockwell C Scale) of Hardened Tooth, Sectioned on Center. Magnified 2¾ diameters

at 1600° F. to a Brinell range of 179 to 217, and rough machined. Then the part is given the "core treatment". Water quenching from 1500° F. will cool it at such a rate that the structure is sorbitic (a fine pearlite, which has excellent strength and toughness, and also has the carbides so finely diffused that they later go into solution in a few seconds when the surface layer is heated). After a high draw, to Brinell 197 to 229, the internal stresses are reduced to a low figure, and the principal physical properties by conventional test methods are: Ultimate tensile strength, 110,000 psi.; yield strength, 70,000 psi.; elongation in 2 in., 22%; reduction of area, 50%; Charpy impact (keyhole notch), 24 ft-lb. All the foregoing are minimum values.

Machinability is also excellent. Finish machining is done on locating surfaces, the teeth are hobbed, and then crown shaved — that is, cut into a slight barrel shape, some 0.008 in. thicker at the center on the pitch line than at the edge — a shape that does much to avoid edge bearing of tooth to tooth and consequent ruinous concentration of stress. (See Fig. 2, page 80, for smudge marks when run against a master pinion.)

Completely machined gears are then preheated to 600° F. in a forced convection furnace, ready for induction hardening. The fixture, shown in Fig. 3, page 80, consists of a horizontal table which can be turned on a vertical spindle, and on which the preheated gear is accurately indexed, so the teeth will be registered later with quenching ports. The table then lowers about 6 in. bringing the gear within the surrounding inductor coil, which it clears by $\frac{5}{16}$ in. The table starts rotating and the current is switched on (all sequences are automatic after the button is pushed once). Within 90 sec., during which time the table is turning to equalize any irregular heating, there is a red hot rim that hugs the surface; the current is then switched off and there is a delay of 14 sec. to allow a little heat to soak deeper and minimize the heat gradient of case to core. During this time the table is brought to a stop and again indexed, then lowered into the quenching fixture immediately below. Start of quenching is shown in Fig. 4, page 81, and it will be noticed that each side of each tooth is hit by a series of water jets at 10 lb. pressure (temperature 75 to 90° F.). Quenching time is 34 sec.; floor-to-floor time about 4 min.

It will be noted that whereas the usual Tocco hardener has a combined inductor block and quenching fixture, the delay between end of heating cycle and beginning of quench permits us to separate these two functions, with consequent simplification of the inductor design. Lastly the gear is tempered for 1 hr. at 300° F., bringing the surface hardness to within limits of C-50 to 60, the hardness of C-50 penetrating to 0.125 to 0.140 in. at the pitch line, all as shown in the adjoining Fig. 5, a hardness survey typical of gears in production. Lastly the center and bolt circle is located from the pitch diameter, and the holes drilled.

Of all the metallurgical problems connected with this development, the hardest one to solve was that of quench cracks at the root of the teeth. It took about a year to solve this problem, and to define the safe limits of basic chemistry and hardenability. While the steel falls within the classification of plain carbon steel, 0.45% carbon, maximum limits for tramp alloys usually observed are 0.10% Cr, 0.15% Ni, and 0.03% Mo.

However, tests for hardenability and notch-bar toughness would catch any less favorable analysis.

Usual tests for cleanliness and freedom from segregation are performed — all, as usual in "Caterpillar" practice, before each heat of steel is released for rolling into billets for this part.

Hardenability restrictions are precise. We find that any steel of hardenability greater than 47 Rockwell-inches* will crack at the teeth roots; any steel of less than 40 Rockwell-inches will not harden to the required depth (C-50 to a depth of 0.125 to 0.140 in. at the pitch line). Such a control of hardenability is exceedingly valuable, since it simply and in one test evaluates a large number of obscure factors related to composition and micro-grain size. Even with these precautions the 600° preheat has been of great advantage in avoiding warpage (gear going out of round) and in helping the quench-cracking problem; our experiments indicate that the stress gradient, center to surface, is decreased about one-third.

Final drive gears made of plain carbon steel in the above manner have been in duty for over 18 months. Experimental work was completed in 1940 and equipment ordered. The proof gears, closely watched in most severe service in lumbering, gave entire satisfaction, so the proportion of new-style gears mounted as rapidly as manufacturing equipment could be installed, over 6000 having been so hardened to date. Conversion has been complete for about 10 months, and the practice is being extended to other models.

Fig. 6 — Transverse Section of Tooth (¾ Size) Etched to Show Hardness Pattern Achieved by Induction Hardening

Many advantages can be cited, but the prime one is that premature service failures of final drive gears in D-8 tractors have been stopped, and the new-style gears accumulate more service hours than the prior types. Some of this is due to the improved tooth form, which eliminates the edge and corner bearing, tooth to tooth, and adapts itself much better to minor misalignments due to tolerances in fit or elastic movements under load. However, it should be remembered that this crown on the gear teeth is only possible because it can be cut into the steel in the soft and machinable condition, and this form *maintained* during heat treatment. Out-of-roundness of this 2-ft. gear after the surface is inductively hardened is on the average 0.007 in. at pitch diameter.

From a cost standpoint the following remarks can be made: Each gear of 1045 steel saves 13 lb. of alloying nickel. Whereas four hardened alloy steel gears would wear out the shaper tools, the crown shaving tools last for hundreds of hours, producing 10 complete gears every 8 hr.

From a test standpoint, the old alloy steel gears were pitted after 100 hr. at full load. The new gears will operate for 3000 hr. under the same conditions and at the end of the time the fine marks left by the shaving tools are still visible. In fact, the dynamometer tests show that the carbon steel gear wears out the nickel-molybdenum S.A.E. 4820 mating pinion.

*Rockwell-inches as a measure of hardenability was proposed to the 1937 Convention by Burns, Moore and Archer in a paper entitled "Quantitative Hardenability". The test is made on a normalized 1-in. round bar of steel, 4 in. long, heated 40 min. in open muffle to quenching temperature recommended in Metals Handbook, quenched in water at 70° F. Bars are then cut in two, transversely, with an abrasive wheel, are surface ground flat, polished to 250 grain alundum, and hardness surveyed, surface to center. "Rockwell-inches" is defined as the area under the hardness-penetration curve down to zero on the C scale. For a 1-in. specimen this is the same as the average hardness of the test piece, surface to center.

CRITICAL POINTS

By the Editor

REMINDED of the well-known incriminating question "Have you stopped beating your wife?" by the receipt of a questionnaire from some self-styled fact-finding organization: "What, in your opinion, is holding up the production of war materials?" and responded "How do you know production *is* lagging?" for numerous observations in many states as well as daily announcements of Army-Navy "E" awards for excellence in production prove that war materials *are* being produced, sometimes in greater volume than can be moved to the front. Likewise, unbalance of consumption and supply of iron, copper, aluminum, is due in no small measure to unexpectedly large production from the new munitions plants. True, there are some surmountable obstacles, and here and there are trouble makers and sore spots, but generally the condition is as represented by the foundry industry, producing at least double the tonnage from old plant despite the draft of many skilled men and supervisors, and hand-to-mouth supply of raw materials. So was reinforced in this main conclusion that the American metallurgical industry — even in the smaller units — is meeting its obligations by a brief visit to General Alloys Co. in Boston, and observing how the foundry had bulged out, forcing all auxiliary departments into surrounding buildings — mostly old tenements and lofts.... HARRY HARRIS, president of the company (that human dynamo with many ideas), believing that the war will last so long as to fray men's nerves, has equipped a downtown office in a studio building, where engineers, salesmen and customers will work in restful surroundings reminiscent of pre-Hitlerite peace, comfort and quiet. Discussed with him the critical problem of tubular alloy retorts for magnesium reduction by ferrosilicon (the Pidgeon process which operates in a vacuum at 2050° F.) and agreed that in this case true economy of alloy and (better) greater and steadier production of magnesium, would be achieved by closer control of the heating furnace, proper support of the 10-in. tube, and a *reduction* in wall thickness from 1⅛ to ⅞ in., the former having a disappointingly low life....Foundry practice on high alloy, heat and corrosion resistant castings naturally involves many special operations.

Americans are really producing

Secrets of high alloy founding

"Secret" of casting thin-walled pots and heat resisting parts is to use rigid, solid patterns, stout steel flasks, everything lined up accurately and held so by close fitted dowels. "Secret" of long life of heat treating equipment that is periodically cooled is a design, a furnace and a heating cycle in use that avoid rapid heating or overheating of a portion of the alloy part, and a metal that resists fatigue from rapid change in thermal stresses — in other words, a design that is free from stress raisers and a metal that is free from inclusions. Melting in a quiet shallow bath (sometimes teaming-up induction and arc furnaces in duplex operation), and handling of all molten metals in preheated teapot ladles that provide three chances to skim, will cut down slag inclusions in the castings; sand inclusions are combatted by all methods well known to foundrymen to prevent mold wash. Chills are used in molds not so much for soundness, which can generally be had from proper gating, but to produce finer grain structure and better fatigue life.

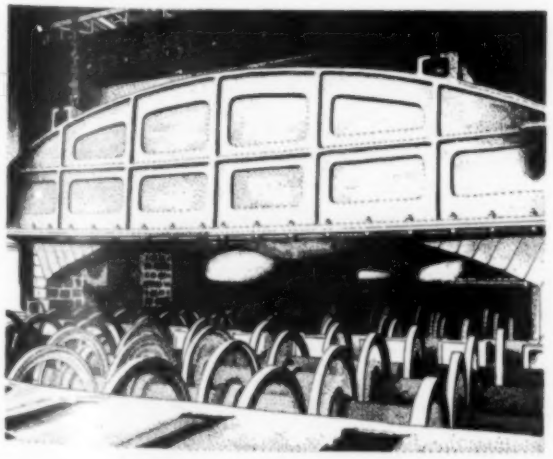
IMPRESSED by the enormous amount of work behind the Curtiss Inspection Manuals, the looseleaf books issued by the Quality Department of Curtiss-Wright Corp., but readily agreed that they save much trouble in the end, what with the necessity of uniform procedure in the various plants and their subcontractors. Likewise, the *number* of inspectors is staggering, one to every 20 "productive" workers, and the educational and turnover problem makes uniformity still more difficult. Lastly, means must be devised for notifying all concerned about changes in details of construction and, at times, major changes in shop practices due to entire changes of models or of materials. For example, SIDNEY SHERIDAN, chief of the materials laboratories in the Buffalo plant, has 100 pages of

Value of detailed inspection manuals

standard laboratory procedure. Especially detailed are the pages on "Control of Torch Welding", describing principally the qualification and certification of aircraft welders. The *nature* of such tests is fixed in the governmental specifications; Sheridan's improvements consist of precise instructions on grading and assessing demerits to each aspect of each type of weld, whereby the welder's relative excellence in per cent of perfect can be computed....Surface treatment in the Curtiss Buffalo plant is a major problem, as well as in any other using such quantities of aluminum. On the one hand, surfaces must be cleaned meticulously of heat treatment film prior to welding; on the other hand, an oxide coat on completed units must be built up, in order to resist corrosion. Anodic coating of bare duralumin gives good protection, but it requires that each piece be individually mounted and electrically connected to a rack — a most laborious proceeding. Consequently, anodic coating is almost completely supplanted by the Aluminum Co.'s very rapid "alrock" process, wherein parts are loosely racked (even held in baskets), cleaned, a very thin surface oxidized by chemical treatment, and the coating then impregnated with sodium dichromate — a corrosion preventive which inhibits the harmful effects of any moisture that may penetrate the final paint coat. All operations are carried on in oversize tanks, some 4x4 ft., 20 ft. long....Also observed two interesting small hardness testers for sorting hardened from soft aluminum parts. Both use the indentation principle, wherein the indenter is forced into the metal surface by a precision spring. One of the devices is known as the "Barcol Impressor" (made by Barber-Colman Co. of Rockford, Ill.). When used at the bench it is hinged at the back, raised and lowered by a foot pedal on the work to be tested, and the depth of impression is automatically registered on a zero-to-100 dial gage calling to mind the Rockwell hardness tester. The other — known as the "Webster Gage" and made by R. A. Webster of Santa Monica, Calif. — is in the form of husky pliers, and so can be carried to a completed ship and test any piece the jaws can grip. The indenter in this case is four-toothed; hard material shows one tiny impression, not-so-hard material shows a second small dent alongside, softest material has the mark of all four teeth. (Instruments with dials marked 1 to 4 are also available.) Unfortunately, however, both these testers are of doubtful value on alclad thicker than 0.040 in., for the soft surface layers of pure aluminum are then thick enough to mask readings which should push through to the harder core to mean anything.

Speedier surface treatments on aluminum

Two new hardness testers



FROM Cleveland to Canton, on over-crowded and belated bus, as guest to the annual dinner of the Electric Metal Makers Guild — that truly technical organization whose meetings are off-the-record and reserved to members and whose membership is reserved to electric melters. Reminded that importance of this group is inverse to its size, for just now the four-fold capacity for electric steel (as measured by American peacetime demands) is reserved for such exacting specialties as guns, bearings, aircraft, and air engine parts. And as to guns, Colonel STEVEN CONNER, commandant at Watervliet Arsenal, said that we are making more artillery in the United States every month than we ever before did in a whole war. Likewise they're bigger and they're good; so far there has not been a single gun blow up in action! (Last war, the Germans lost about 25 guns — and gun crews — per million rounds.) Confidential discussions by Guild members, naturally, dealt with the maintenance of perfection despite ever-decreasing quality of raw materials, refractories, and labor. That privacy, which is so necessary for frank discussion of techniques, unfortunately prevents proper exploitation of the Guild itself, and retards a wider appreciation of its importance by the managerial end of the steel industry, for methinks many of the compliments tossed by the Army and Navy to the American Iron and Steel Institute at its recent New York meeting should have been fielded right on over to the melters in the electric steel shops.

Big guns— safe for us, deadly to the enemy

This short paper follows the line of a 10-min. contribution to one of the round table discussions at the last convention. It cites the precautions necessary for using the standard hardness tests, as well as the relatively new and special Barcol and Webster testers described in the "Critical Point" on page 84, and then goes on to give reasons why a universal conversion table is impossible to construct. Rather each individual testing department should work out conversions which apply to the particular alloy, gage, and temper it is working with.

HARDNESS OF ALUMINUM SHEET

(tests and conversion charts)

By RICHARD L. TEMPLIN

Assistant Director of Research and Chief Engineer of Tests, Aluminum Co. of America

AMONG the hardness tests which may be applied to aluminum sheet are the Brinell, Rockwell, Vickers, Barcol, Webster, and Shore. Of the six hardness tests mentioned the first five are all essentially static penetration tests whereas the sixth is a type of impact test, but the remarks to be made concerning their uses and limitations will also apply to other similar tests that might be used.

In making the Brinell, Rockwell, Vickers, and Barcol tests, a load is imposed on a penetrator of given size and shape and the resistance to penetration (hardness of the specimen) is obtained as a numeral representing either *(a)* the unit resistance (load divided by area) of the material or *(b)* the depth of the impression. In the Webster hardness tester the number of visible indentations, 1 to 4, is simply noted. In the Shore test a small tup having a given contour on its lower end is dropped from a specified height onto the specimen and the height of rebound, as determined by an arbitrary scale, is taken as the hardness of the material tested.

While any one of these hardness tests can be used on sheet aluminum, satisfactory results require careful consideration both of the factors affecting the test results and of the use to be made of the data obtained. By far the majority of troubles experienced with hardness tests on aluminum (and doubtless in other metals as well) result from a lack of appreciation of these two salient points.

Factors Affecting Test Results

Let us first consider briefly the factors affecting the test results.

Experiences of many users of these hardness tests on a wide variety of metal products have clearly shown the need for close adherence to definite procedures in carrying out the tests, if satisfactory results are secured. Because of this, standard or tentative standard methods have been adopted for the more widely used tests such as the Brinell and Rockwell. These specify the verification of loads, the size and shape of penetrators, and the duration of load application. See, for example, A.S.T.M. specification E18-39T on Rockwell Superficial Hardness Test.

The proper surface preparation of test specimens, while important in many aluminum products, does not require much attention when testing aluminum sheet for hardness. An exception to this statement is sheet which has a thick anodic coating. Such a coating affects the hardness values obtained, depending upon the thick-

ness and hardness of the coating as well as the particular hardness test used.

Variations in the thickness of aluminum sheet affect hardness values in two ways. Since the thickness of the test specimen should not be less than about 10 times the depth of the impression, it is necessary to select a suitable load-penetrator combination which will comply with this requirement. Secondly, in the case of alclad aluminum sheet the thickness of the surface layers is intended to be a constant percentage of the over-all thickness of the sheet, with the result that the thickness of the layers increases with the specimen thickness. Since the cladding is soft, pure aluminum, it will therefore generally be found that the observed hardness of alclad sheet of a given type and treatment decreases as the thickness of the sheet increases. For example, alclad 24S-T sheet varying in thickness from $\frac{1}{32}$ to $\frac{1}{4}$ in. will decrease in Brinell hardness range from 40 to 75%, depending on the combination of load and ball-size used.

In measuring the hardness of any aluminum sheet careful attention should be given to the method used for supporting the specimen. This is particularly true for the thinner specimens. The surface on which the specimen rests should be flat and smooth, and the support itself should be so designed and in such mechanical condition that no movement of the specimen will occur during the test. The specimen should rest solidly on the support directly under the penetrator.

Aluminum sheet is furnished in many different alloys and these in turn in different tempers. The alloys are the result of different chemical compositions. The tempers are obtained by various amounts of cold working, different heat treatments, or by a combination of heat treatment and cold working. As a result there is available a wide variety of combinations of tensile strength, yield strength, and elongation, as well as pronounced differences in work-hardening capacities of the sheet. These facts, therefore, suggest what will be emphasized later, namely, that we should not expect to find any generally applicable and simple relationship between hardness and the other mechanical properties such as tensile strength.

"Watchdogs" Is the Title of this Photograph of Hardness Testers at Jessop Steel Co., Taken by T. S. Fitch

Uses of Hardness Data

Since there are available so many different hardness tests together with many combinations of load and penetrator (as exemplified by the Rockwell test), and since it is unusual for a laboratory to possess all kinds of hardness testing equipment, there has arisen a demand for suitable conversion tables which will permit of translating hardness values obtained from one of them into corresponding values which might be expected

from another. The most optimistic of those interested in such conversion tables have hoped that a single table would cover all hardness tests and all metallic materials. Relatively little investigation is required to demonstrate the futility of attempting to prepare such a conversion table. Further investigation results in separating cast from wrought metals, then ferrous from nonferrous, and subsequently the consideration of only one alloy, temper, and form of product, for most satisfactory results. For example the hardness conversion chart devised by Scott and Gray on page 524, *Metal Progress* for October 1941, applies only to *hardened* steels; the one on page 235 of February 1943 does not apply to all brasses, only to 70 Cu, 30 Zn or cartridge brass.

Many, perhaps most, of the penetration hardness tests have limitations imposed by variations in the geometry involved in using various combinations of loads and penetrators. For example, in the Brinell test, when the ratio of load to the square of ball diameter varies, the resulting hardness values vary with the work-hardening capacities of the specimens. This difference in geometry also affects the comparison amongst the different kinds of hardness tests. For instance, an accurate comparison of Brinell hardness with diamond pyramid hardness is possible only when the Brinell ball impression is about three-eighths the diameter of the ball. When this ratio has this value, the amount of strain-hardening that occurs when making the Brinell test is substantially the same as obtains in making the diamond pyramid hardness test.

These facts, together with quantitative data showing the discrepancies in certain conversion charts pertinent to these hardness tests, have been ably presented by Robert H. Heyer, metallurgist for American Rolling Mill Co., in his recent paper on "Hardness Conversion Relationships" before the A.S.T.M. (Vol. 42, 1942, p. 708). This same paper discusses conversion data for certain Rockwell scales that might be used in testing aluminum sheet.

Another commonly attempted use of the hardness test is for estimating the tensile strength of wrought metals. In some instances this has proved quite satisfactory, and has fostered the idea that it should be applicable to all wrought metals. Relationships between tensile strength and some of the hardness tests have been determined which would appear, tentatively, to be satisfactory for a few of the different kinds and tempers of aluminum sheet. The investigational work done so far has shown that the ratio between tensile strength and Brinell hardness for the various kinds of commercial aluminum sheet varies from about 470 to 640; in the case of 24S-T sheet, however, the ratio of 600 appears to give satisfactory results if the other factors involved are accorded proper consideration.

Since there is a wide variation in ratio of *fatigue* strength to tensile strength throughout the various kinds of aluminum sheet there is no simple relationship which will permit any hardness test to estimate the fatigue strength of aluminum sheet. The same can be said for the shearing strength of aluminum.

Check on Heat Treatment

Occasionally it is desirable to use hardness tests for determining whether or not aluminum sheet has been fully annealed or properly heat treated. If the type of alloy is known there is usually no question about any of the hardness tests being satisfactory for determining the fact that the material either has been annealed or not annealed, heat treated or not heat treated. If reasonable care is exercised in making a Brinell or Rockwell test, the results obtained should indicate within acceptable limits whether or not the heat treating operation was properly done. On the other hand, if an attempt is made to rely upon any hardness test to determine whether or not aluminum sheet meets guaranteed minimum tensile properties, a doubtful answer may be expected, particularly if the material has properties near the limits specified. However, some of the hardness tests, particularly the Rockwell and Brinell, are quite satisfactory for checking individual sheets which are to be used in a drawing or forming operation, for the purpose of catching off-temper samples. With proper attention given to variations in hardness resulting from differences in thickness of sheet, this use may also be extended to alclad sheet with satisfactory results.

Another use of hardness tests is found in separating mixed lots of aluminum sheet of different kinds or tempers. This can be done quite satisfactorily if there are suitable differences in the hardness values of the varieties of sheet involved. The Webster and Barcol hardness tests are particularly useful for this purpose on account of the facility with which they can be used under various plant conditions.

In view of the foregoing remarks it is suggested that the best results will be obtained in the application of hardness tests to aluminum sheet where the parties directly interested in their use work out their own conversion tables and factors for the specific problems encountered rather than ask for tables for all kinds and thicknesses of aluminum sheet.

Compiled by F.R. Morral

ELECTROPLATING METALS

Metals	Plating Solution; Grams per Liter	Anodes	Current Density; Amp/Sq.dm.	Voltage; Volts	Temp, °C	pH	Current Efficiency; %	Thickness Coating	Uses	Ref.
Lead (continued)	$2(PbCO_3)Pb(OH)_2$ 300 50 % HF 48.0 H_3BO_3 21.2 Glue 0.2		0.54-7.6 (av. 3.2)				100 %	up to 1.27 mm.	Barrel or still plating	10
	Pb 75 Total fluosilicate 150 Glue 0.2		0.54 to 8.8	0.1 to 0.2	35-40		100 %		Cheap for large scale operations. Decomposes easily	
	Sulfamate Pb process Sp. gr. soln. 30° Be		0.5 to 4.5	(a) 3-8 (b) 9-14	25-50	1.3-2.0 (av. 1.5)	100 %		Lubricant in wire drawing.	11
Nickel	$NiSO_4.7H_2O$ 240 $NiCl_2.6H_2O$ 45 H_3BO_3 30 Anti-pitting agent	97 % Ni, rolled depolarized	4.3		45	1.5-3.0 4.5-5.6	90-100		Bright Ni deposits; grain size less than 0.0001 mm.	12 26
Platinum	NH_4NO_3 100 $NaNO_2$ 10 $Pt(NH_3)_2(NO_2)_2$ 16.5 NH_4OH (28 %) 50	Pt	0.44	2.4		6.4-7			Use nickel undercoat	13
Palladium	$PdCl_2.2H_2O$ 3.7 Na_2HPO_4 100 $(NH_4)_2HPO_4.12H_2O$ 20 $C_7H_6O_2$ 2.5	Pt or Pd	0.2-0.3	1-2	50	7			Plate directly, or over flash Ni undercoat	14
Rhodium	H_2SO_4 (conc. C.P.) 20 Cc. Rh. metal preparation (Concentrated Solution) 2 H_3PO_3 (ortho) 85 % 40 Cc. Rh. prepared 2.0	Insol. Pt	1-11		40-50				Use bright Ni undercoat	15
Ruthenium	$RuNOCl_3$ 4 H_2SO_4 conc. C.P. 20 Cc.		2.2	2.5						16
Silver	Ag metal 25-33 KCN (free) 30-45 K_2CO_3 30-90 CS_2 up to 0.0009	Ag 999.5 fine	0.5-1.5		24-32 (av. 27)	11.5-12	100 %			17 27
* Tin	$SnSO_4$ 30-90 H_2SO_4 30-150 Addition agents (various) 0.5-3.5.0	Pure Sn	1.1-4.3 (also up to 43)	0.6-1.6	21-27		95-100			18
	$Na_2SnO_3.3H_2O$ (a) 90 (b) 150 NaOH 7.5 18.8 Na Acetate 15 22.5 H_2O_2 (100 vol.) 0.5 0.5	Pure Sn	1.08-4.32	4-6	60-80		60-90		19 μ satisfactory for steel; 7.6-12.7 μ for non-ferrous metals.	19
Zinc	$ZnSO_4.7H_2O$ 240-550 NH_4Cl 15-30 Addition Agent: $Al_2(SO_4)_3.18H_2O$ or $AlCl_3.6H_2O$ or $NaC_2H_3O_2.3H_2O$	98.5-99.9 % Zn	1-3 (also up to 200)	4	24-30	3.5-4.5	99	0.0038 to 0.025 mm.		20
	$Zn(CN)_2$ (a) 60 (b) 90 NaCN 23 37.5 NaOH 53 90	99.75 % Zn	(a) 1-2 (b) 6-12		(a) 40-50 (b) 40-70		(a) 90-95 (b) 85-95			21
	$Zn(CN)_2$ (a) 37.5 (b) 60 NaCN 22.5 30 NaOH 30.0 45 Hg Salt 0.25 0.25	98.25 % Zn + 0.5-1 % Hg	1.1 to 1.6 (anode) up to 43 (cathode)	4-6	40 (30-50)		90			22
	$Zn(CN)_2$ (a) 60-82 (b) 60-82 NaCN 18.7-64 34-75 NaOH 75-112 75-97 Addition Agent	99.8 %; Zn + other Zn-Al-Hg; Zn-Mg	0.2 to 10.7	(a) 1.5-6 (b) 10-15	20-45 prefer 27.8-37.8		75-95		Bright plate	23
Indium	For details see reference									24

(11) Am. Electroplating Society, June 1942; Modern Electroplating: (12) p. 239; (13) p. 278; (14) p. 279; (15) p. 281; (16) p. 283; (17) p. 293; (18) p. 320; (19) p. 333; (20) p. 346; (21) p. 365; (22) p. 366; (23) p. 369; (24) Steel, November 9, p. 80 (1942); (25) J.L. Bray and F.R. Morral. The Surface Treatment of Metals.-A.S.M. 1941, p. 108; (26) W.S. Loose, Nickel Plating Magnesium Alloys. Trans. Electrochem. Soc. 81, (1942), Prepr. 6; (27) F.J. Bowen and L.I. Gilbertson. The Electrodeposition of Silver on Magnesium, Trans. Electrochem. Soc. 83, (1943), Prepr. 1.

Note: In all electroplating of metals a standard procedure has to be followed. This consists of 4 fundamental steps. (25): (1) Preparation of the surface to be coated. (2) Activation of this surface. (3) Actual coating. (4) Finish of the coating. The details vary for the various metals. Some electrodeposits do not adhere directly to the basic metal and undercoats of metals adherent both to the basic metal and the coating have to be used. Certain metals offer difficulties in preparation. Magnesium is a good example. Special techniques using special electrolytic solutions have been developed (26, 27).

* Note: Fusion of tin on electrotinned strip by induction heating has been developed to close pinholes. G.E. Stoltz; Blast Furnace & Steel Plant 30, p. 1357 (1942).

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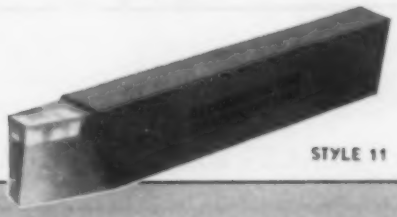
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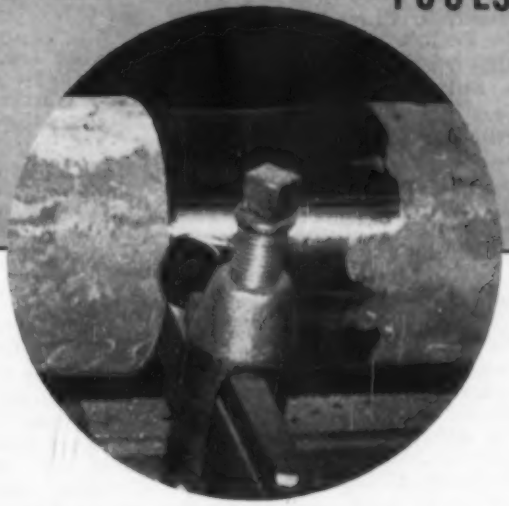

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Abrasive belt polishing machines. Divine Brothers Co. Bulletin Kf-434.

Abrasive cloth gadgets. Behr-Manning Corp. Bulletin Nf-467.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin Fg-327.

20-page booklet on cutting fluids has been issued by Tide Water Associated Oil Co. for the metal working industry. Bulletin Gg-515.

Many applications for the Norton open structure grinding wheel are shown in leaflet issued by the Norton Co. Buletin Gg-88.

New catalog describes metal forming machinery engineered and manufactured by the Yoder Co. Bulletin Gg-520.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin Gg-222.

FERROUS METALS

New war time edition of the machinery steel selector has just been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin Fg-264.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin Kf-429.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin Ox-74.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin Nf-312.

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 154, 156, 158, 160, 162, 164 and 168.

Metal Progress 7301 Euclid Ave., Cleveland
Send me the literature I have indicated below.

Name ..... **Title** .....

Company ..... **Address** .....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 8 pages.

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Eg-500	Eg-161	Fg-238
Ff-105	Fg-361	Kf-230
Ff-394	Ag-470	Kf-434
Ff-132	Cg-363	Nf-467
Ec-113	Dg-486	Fg-327
Ke-118	Kf-433	Gg-515
Af-335	Eg-454	Gg-88
Ef-360	Eg-297	Gg-520
Cg-479	Eg-501	Gg-222
Fg-465	Eg-278	Fg-264
Dg-491	Eg-496	Kf-429
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Hf-8a	Fg-508	Cg-478
Kd-85	Af-337	Cg-483
Cd-255	Kf-437	Dg-134
Ce-76	Eg-126	Gg-523
Ld-298	Kf-455	Ag-331
Ld-295	Kd-89	Ne-86
Kd-229	De-307	Ff-393
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Gg-522	Ff-395
Eg-67	If-401
Eg-134	Ff-320
He-6	Bf-345
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Ke-37	Cf-22
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Nf-3	Gg-110
Ag-466	Gg-524
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Ce-35	

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Ef-386	Lf-203
Ef-323	Ce-302
Kf-388	Ff-321
Ag-310	Bf-183
He-41	Eg-445
Nf-154	Hf-49
Cg-476	Lb-25
Fg-116	Lf-55
Fg-131	Lf-461
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Fg-510	Lf-145
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Lf-44	Cg-226	Gd-2
Lf-463	Cg-11	Dg-38
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Ff-286	Kf-446	Be-82
Ff-155	Kf-439	Nf-305
Df-60	Kf-447	Bb-187
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Ef-379	Dg-487	Ke-260
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He-184	Gg-514	
D-17	Gg-518	
Bb-84	Gg-519	

The author contributed a brief account of the radiographic practices necessary to comply with government specifications to a round table discussion on inspection methods at the last Convention, and later was able to release for publication in Metal Progress a full set of the radiographic standards set up about a year ago to govern acceptance of structural castings for airplanes. Representative negatives are reproduced in this article. Those eliminated are either of similar defects which did not register strong enough to appear on an engraving without retouching, or of defects readily observed by visual inspection without X-ray.

X-RAY INSPECTION OF CASTINGS

(ARMY AIR FORCES' REQUIREMENTS)

By ROBERT KATZ

Assistant Radiologist, Army Air Forces Materiel Center, Wright Field

TOWARDS the end of 1941 it became imperative that general standards for the acceptance of aircraft castings be established. At that time the commercial standards for the acceptance or rejection were largely intangible; castings rejected by one radiographic laboratory were later accepted by another. As a check on the validity of commercial X-ray inspection, rejected castings were subjected to breakdown or tensile tests conducted upon specimens machined from castings, and many were found to have strengths considerably in excess of design or specification values. Pressure of increased aircraft production made such a waste of material intolerable. As remarked at the outset it became necessary to establish an inspection procedure which would insure that:

1. No casting which might fail would find its way into an airplane structure.
2. A minimum number of usable parts would be discarded by unnecessarily rigid inspection standards, and
3. The inspection procedure be as economical of manpower and materials as was consistent with the first two aims.

To achieve these ends, a procedure for the X-ray examination of *structural* castings which attempted to resolve these principles was adopted by the Army Air Forces in February, 1942. An outline of the procedure and some representative radiographs will be given, principally applicable to sand and permanent mold castings of aluminum or magnesium alloys used in the airplane's structure. Castings for use in hydraulic systems need not be X-rayed if they are hydrostatically tested unless sections of these castings are also subject to structural loads, whereupon such *sections* are subject to the same requirements as structural castings.

Allowable Stress — In the design an allowable stress is permitted of half the minimum specified ultimate strength, as determined on separately cast test bars. Castings may be designed for no X-ray inspection provided that ultimate design loads will not produce stresses in excess of 20% of the allowable stress (10% of minimum test bar strength) and such castings are known as Class B castings. Castings designed so that the ultimate design loads produce stresses between 20 and 100% of the allowable stress are called Class A castings, and must be radiographically examined and statically tested as outlined below:

Test Lot — Once preliminary design and foundry development have been completed, and production pattern equipment has been prepared, a test lot, consisting of the first 100 castings of the first production run of each Class A design, must

be 100% X-ray inspected with special reference to stressed sections. The three worst castings of this test lot, as graded by the radiographs, are then machined and tested so as to simulate the loading of the castings as installed in the airplane. Radio-

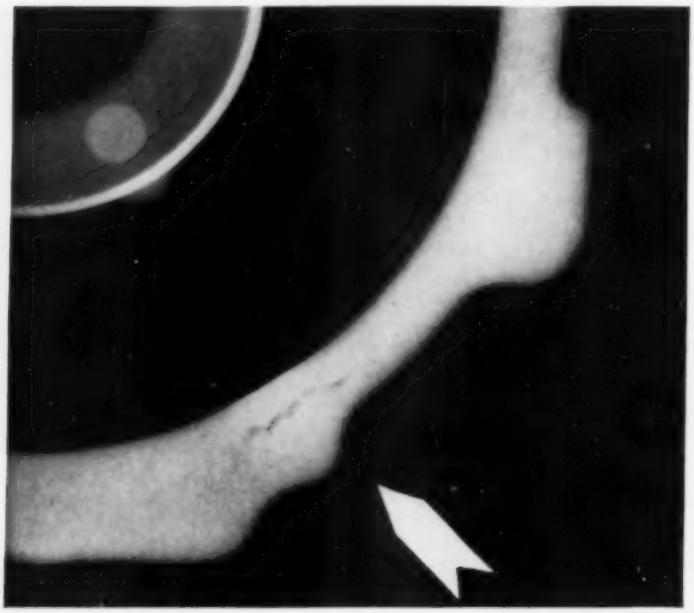


Fig. 1 (Radiograph No. 3 of Standard Set) Shows a Shrinkage Cavity in an Aluminum Alloy Permaent Mold Casting; Not Acceptable

graphs of the three test castings become acceptance standards for all other castings of the same design, if the weakest casting withstands a test load of 1.5 times the design load (1.25 times for steel centrifugal castings).

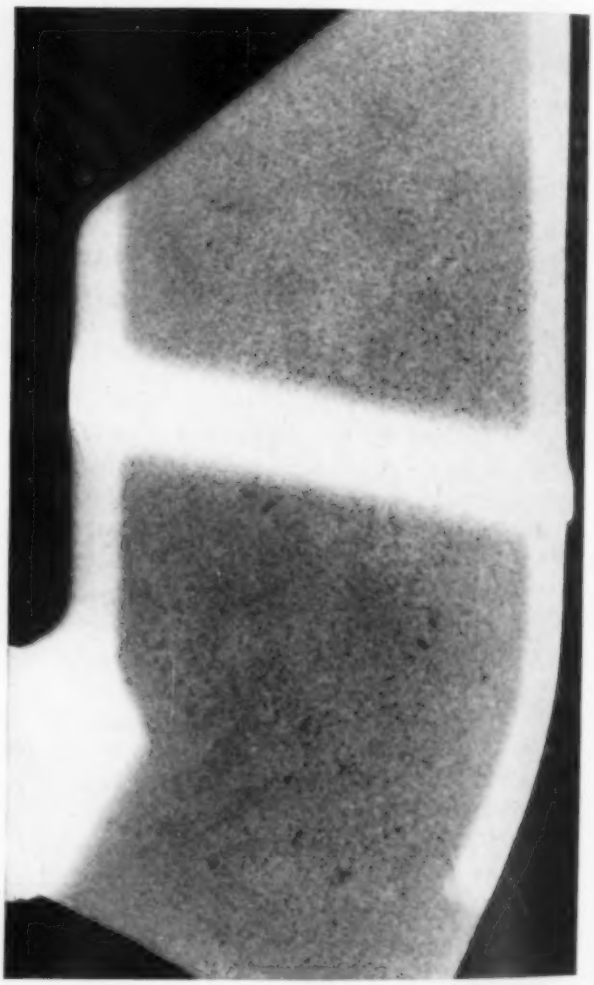
Should the test castings prove too weak, sounder castings may be selected from the test lot until satisfactory radiographic standards are obtained.

The Army inspector may reduce the size of the test lot for complicated castings which are expensive to radiograph. Where fewer than 100 castings are required of a particular Class A design, the entire lot of castings constitutes the test lot, but only one need be statically tested.

In the course of production, casting quality may vary sufficiently from the test lot so that a revision of the X-ray standards is desirable. The contractor may revise these standards at his option by repeating the X-ray and static test procedure upon any group consisting of 100 consecutive production castings.

Production Runs—Lots subsequent to the test lot are radiographically inspected on a percentage basis according to the ratio of test loads and design loads of the weakest of the test castings. Where this ratio lies between 1.5 and 3.0 (1.25 and 3.0 for steel centrifugal castings), all castings in the order or production run are given 25% inspection and are called Class A-1. Class A-2 castings are those in which the ratio of test to design loads lies between 3 and 10, and receive 10% inspection. Where the ratio is greater than 10, castings receive no X-ray inspection and are called Class A-3. When 1% of the original sampling (the 25% for Class A-1, or the 10% for Class A-2) is found inferior to the standards, 100%

Fig. 2 (Radiograph No. 10 of Standard Set) Shows Generally Distributed Gas Porosity in an Aluminum Alloy Sand Casting, Which Is Undesirable, but Acceptance or Rejection Would Be Based Upon the Static Test



inspection of the balance of the lot may be required.

Substandard A-1 castings are rejected, but substandard A-2 castings are placed in salvage. Castings whose defects cannot be judged from the standard radiographs are similarly placed in salvage. Castings which receive no X-ray inspection are subject to visual inspection.

Illustrative Radiographs

In addition to the requirements of static test, no Class A casting is acceptable which contains defects of a localized, stress raising type. Thus cracks, cold shuts, misruns, shrinkage voids (Fig. 1) are automatic cause for rejection. [EDITOR'S NOTE: Cracks, cold shuts and misruns are all readily found by visual inspection, and the radiographs in the standard set of 17 that show them are not reproduced on these pages, in the interest of saving space.] Defects of a general type which do not act as stress raisers are considered undesirable, but are judged solely on the basis of the static test simulating the working loads on the complete part, as previously outlined. Such defects include gas porosity (Fig. 2 and 3), blowholes (Fig. 4), segregation (Fig. 4), microshrinkage (Fig. 5 and 6), dross and sand inclusions (Fig. 7) and mottling (Fig. 8). Defects of a general type which are so aligned as to cause stress concentration are immediate cause for rejection (Fig. 9).

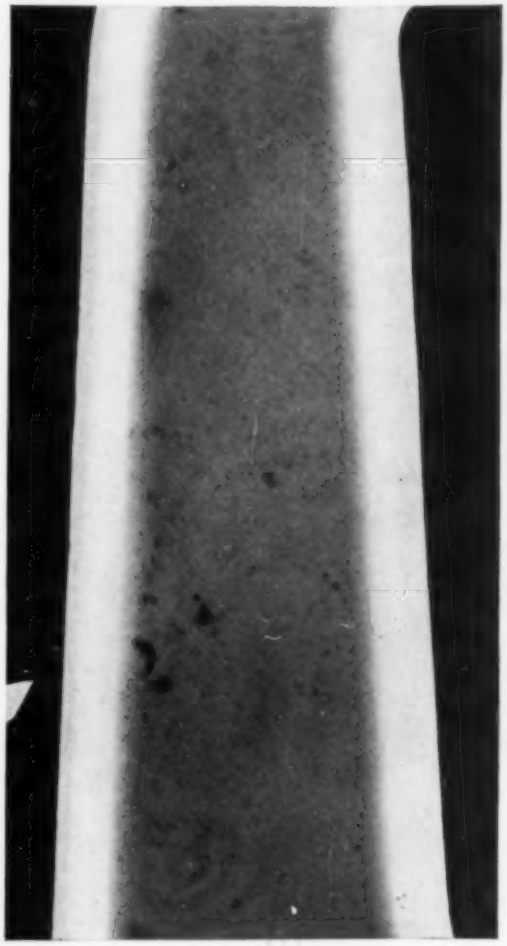


Fig. 4 (Radiograph No. 16 of Standard Set) Shows Round Blowholes and Irregular Segregates in an Aluminum Alloy Sand Casting, Which Are Undesirable, but Acceptance or Rejection Would Be Based Upon the Static Test

Fig. 3 (Radiograph No. 11 of Standard Set) Shows Elongated Gas Porosity in an Aluminum Alloy Sand Casting, Which Is Undesirable, but Acceptance or Rejection Would Be Based Upon the Static Test

Certification of Laboratories — The commercial radiography of Army aircraft castings has been restricted to an approved list of certified laboratories. Certification is set up on the basis of a simple test which requires a laboratory to prepare radiographs of a set of six castings equal to radiographs previously prepared at Wright Field. The required positioning is specified so that direct comparison of the quality of the X-ray films can be made. At this writing about 40 laboratories scattered throughout the United States have been approved. A laboratory failing the first test will be re-tested upon application. Certification may be withdrawn when radiography in production fails to meet Army Air Forces requirements. Thus, each production radiograph must bear the clearly defined image of the applicable penetrameter sensitivity gage.

Certification simply permits an organization to take X-ray pictures, but does not authorize the laboratory to

Fig. 5 (Radiograph No. 12 of Standard Set) Shows Feathery Microshrinkage in a Magnesium Alloy Sand Casting, Which Is Undesirable, but Acceptance or Rejection Would Be Based Upon the Static Test

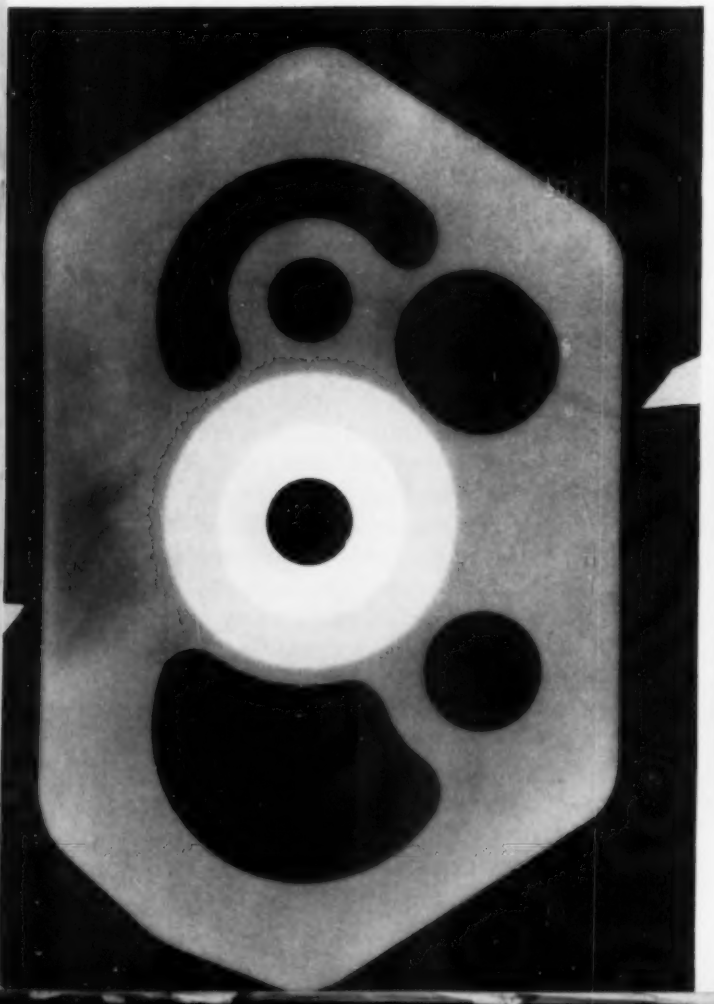
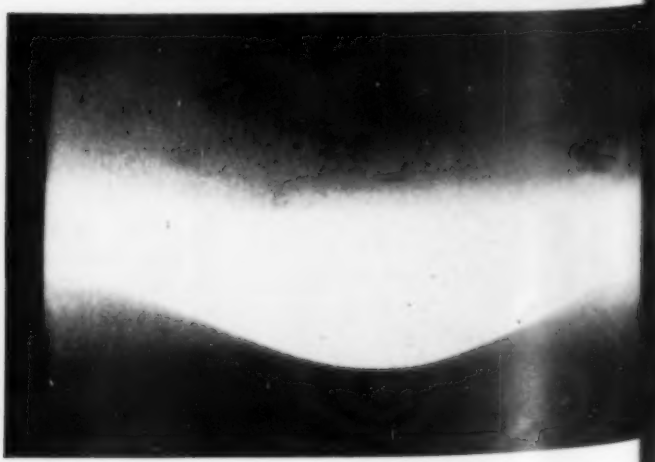


Fig. 6 (Radiograph No. 2 of Standard Set) Shows a Magnesium Alloy Sand Casting With an Accumulation of Microshrinkage at Left, Which Is Undesirable, and a Crack at Right, Which Is Not Acceptable

Fig. 7 (Radiograph No. 17 of Standard Set) Shows Dross and Sand Inclusions in an Aluminum Alloy Sand Casting, Which Is Undesirable, but Acceptance or Rejection Would Be Based Upon the Static Test



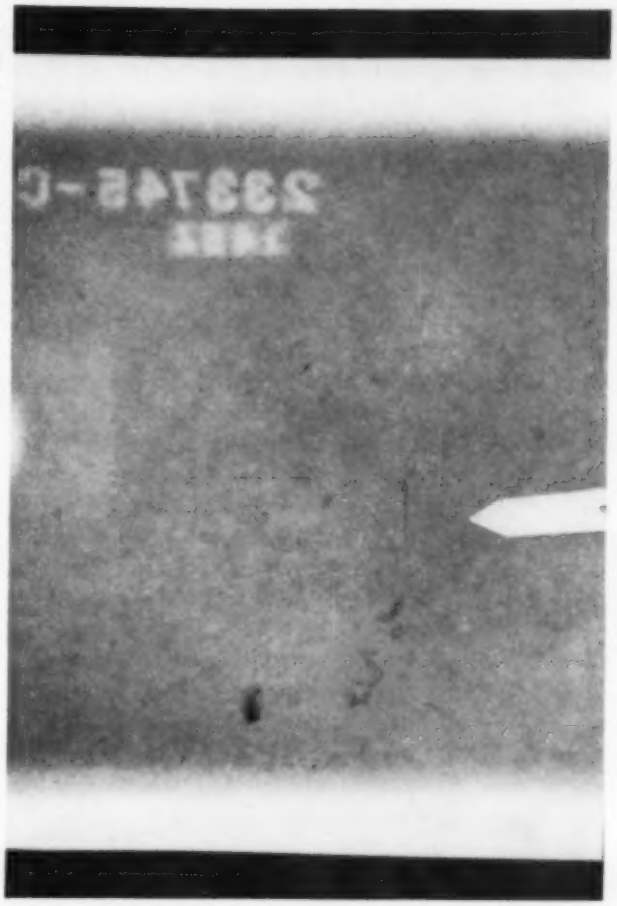


Fig. 8 (Radiograph No. 1 of Standard Set) Shows a Crack Which of Course Is Not Acceptable. It also shows "mottling" throughout the web of this aluminum alloy sand casting which is not a cause for rejection. [Editor's Note: — Mottling always appears as the casting temperature rises, and is therefore to be expected in castings of large size or complexity.]

accept or reject castings. Responsibility for structural castings, as well as for all parts of the airplane, rests with the prime contractor (the airplane manufacturer). The laboratory may not accept or reject castings for the prime contractor unless authorized in writing by the prime contractor, and a copy of the document furnished the Army inspector.

Terminology — Radiographic inspection has been much confused by the absence of a uniform, precisely defined terminology for the markings appearing on the radiograph. The same defect has been described as "gas porosity", "pinholing", "wormholing" and "pepper and salt porosity". The following definitions of various discontinuities have therefore been adopted:

Cracks are represented by darkened lines of variable width which are dendritic when caused

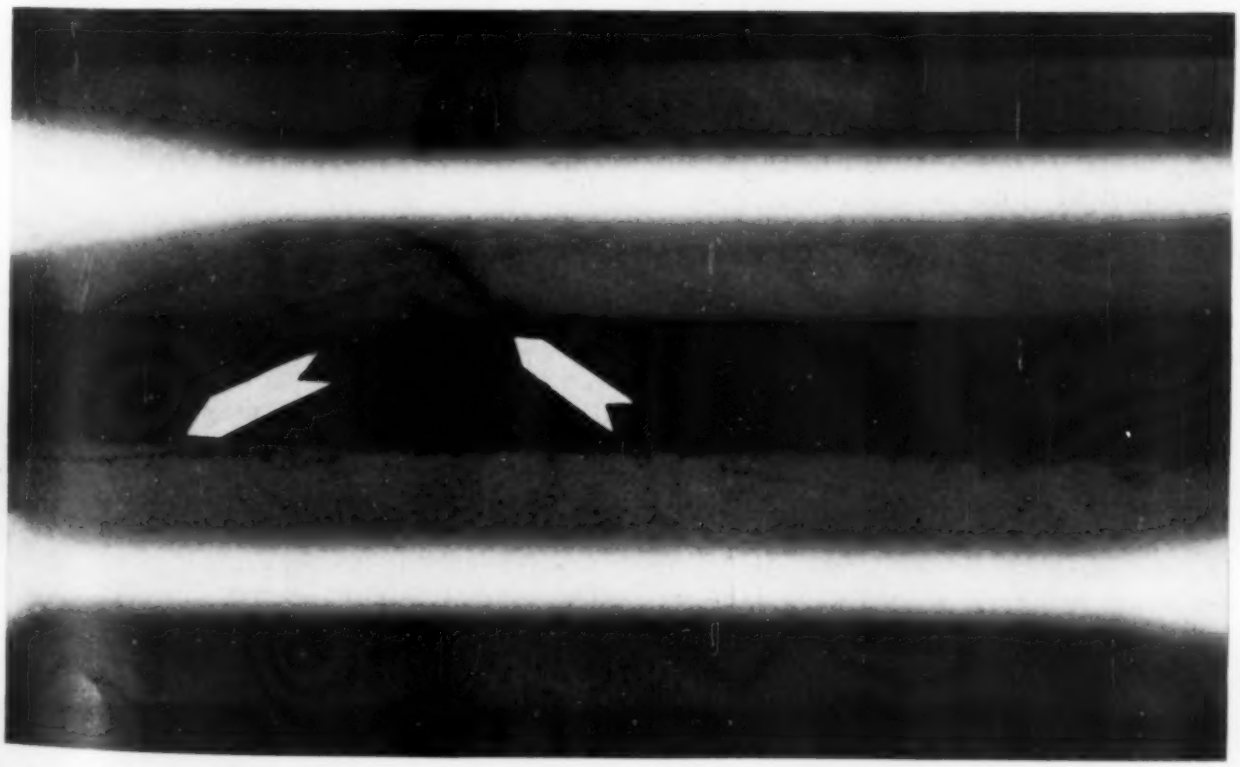


Fig. 9 (Radiograph No. 8 of Standard Set) Shows Pronounced Gas Porosity — Especially in Lower Casting — and Blowholes in Linear Formation. Not Acceptable

by hot shortness, and are more nearly linear, or straight, and of more constant width when originating from residual stresses in solid metal.

Shrinkage. Shrinkage cavities are represented by dendritic or filamentary dark regions of irregular dimensions and indistinct outline, and are caused by an insufficient supply of molten metal to feed the particular section.

Cold Shuts are represented by darkened areas of variable length and smooth outline which tend to be elongated and thin. They occur where the streams of molten metal have come together and have failed to weld together, so that the contact surfaces are oxidized. Cold shuts may generally be detected by visual examination.

Misruns appear as darkened areas of variable dimensions and smooth outlines where the molten metal has failed to fill the section. Misruns can always be seen by visual examination.

Gas Porosity is generally found in aluminum alloy castings and is due to the presence of dissolved hydrogen in the molten metal. It appears as a well distributed peppering of round or irregular dark spots which tend to be elongated or curved in coarse grained castings. The porosity is distributed throughout the casting, the size of the holes varying with the gas content of the metal and the rate of solidification of the section.

Microshrinkage commonly appears in magnesium alloy castings, and occasionally in castings of other alloys, as dark feathery streaks, or as massive areas of fairly definite outline.

Blowholes or gasholes usually appear as well defined spherical or rounded darkened areas. They are caused by trapped air, mold or core gases, or water vapor and are random in occurrence but tend to distribute on the cope side of a casting.

Dross Inclusions. Dross or oxide inclusions appear as small darkened regions of irregular or indistinct outline, varying in intensity. These tend to be random in occurrence but may become localized in the cope side of a casting.

Sand Inclusions appear as gray spots of uneven granular texture with indistinct outline. They are random in occurrence but tend to concentrate near the drag side of a casting.

Segregation of metallic inclusions (whether or not these properly constitute alloying elements) appear as well defined white spots or as mottled areas, regular or irregular in shape.

Mottling appears as a pattern of alternate light and dark areas which tend to the size and shape of the macroscopic grains and is due to the difference in chemical composition between the grain and grain boundary material; most frequently found in aluminum alloy castings.

Quench Out!

ONE of the important rules in heat treating is: "Be sure the steel is quenched out." This refers not to how cold the piece is quenched — a vital factor itself — but to the necessity of cooling fast enough to avoid the separation of ferrite from the transforming austenite. If this happens, the quenched structure will contain martensite plus ferrite; the latter is soft and weak, affording interruptions of the continuity of the structure and providing a likely path for failure under high loads. Similar reasoning applies to mixtures of other structural constituents.

There is ample evidence in the literature as to the poor physical properties of mixed structures, and this point probably needs no proof even though it is so often forgotten. It is readily apparent that if you have a structure which is mostly Rockwell C-40 hard after quenching and drawing, having a tensile strength of about 180,000 psi., yet containing zones of ferrite with tensile strength of 50,000 psi., the latter will detract from the strength of the whole, without helping the ductility. In fact, elongation and impact are damaged because of the localizing of deformation in the ferrite films which thus act as notches.

As far as hardness alone goes, "quenching out" is not essential if the piece is to be drawn back at 800° F. or higher. If the piece as quenched has one area of Rockwell C-60 and one of Rockwell C-45, and is then drawn so that the C-60 part drops to C-40, the C-45 part will also come out not far from Rockwell C-40, because a definite draw temperature establishes a certain carbide particle size in the tempered martensite, and this is a prime factor for determining hardness.

But most important to the heat treater is the fact that "quenching out" reduces distortion and cracking. One proof of this was given by Stuart Oliver in *Metal Progress* for October 1935. He found that quenching S.A.E. 1040 shafts so that hardness was high and uniform gave best straightness. I also believe that the real advantage of press quenching of gears lies in the better *uniformity* of quenching which decreases distortion; the actual gripping or holding effect of the dies is slight. Parts which are hardened from atmosphere controlled furnaces may be expected to give more uniform movement because of uniformity of hardening. Parts spun while quenching will quench more uniformly and hence be

BITS AND PIECES

METALLURGICUS' OWN DEPARTMENT

(An ⬢ book of your choice for a publishable item)

straighter. Many more examples could be cited.

When the forces producing distortion are greater than the metal will tolerate, the piece cracks. Cracking is apt to result from non-uniform quenching. It is often surprising to find such things as the following, but the results are reasonable and logical: Shafts of S.A.E. 1035, with flanges, threads, and crossed cotter holes, were being water quenched, and about 10% were cracked in the threads or on the flange; changing to a more drastic 3% caustic solution for quenching reduced distortion and eliminated cracking. Another example: Long shafts of S.A.E. 1050 were quenched in oil, resulting in bad warpage and poor physical properties; when a time quench in caustic was used, warpage was greatly decreased and toughness much improved.

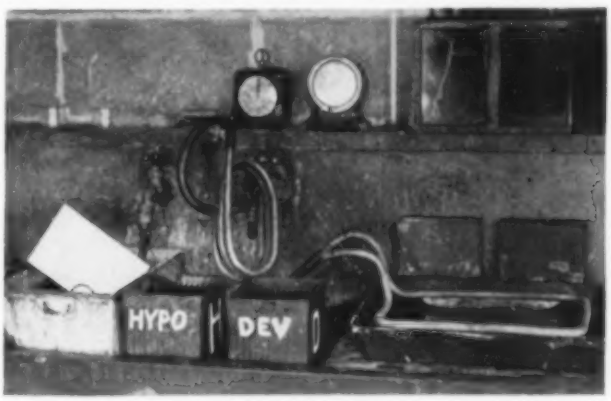
These remarks all refer to the difference between quenching to essentially 100% martensite, and quenching to mixed microstructures (part ferrite plus martensite, fine pearlite, or bainite). Similar behavior is discovered when quenching produces martensite plus fine pearlite. In all cases mixed structures have bad effects on physical properties and on warpage.

METALLURGICUS

Time Saver in Dark Room

MY BEST time saver: We used to forget to cool the plate developer and hypo before taking pictures. With three quarts of developer in a hard rubber developing tank, it took about an hour to lower its temperature from 90 to 70° F. by just setting the tanks in a sink of running water. To pour the solution out in a glass dish to cool it faster is mussy — and still slow.

In 1932 Donald Boone, a graduate assistant



Tap Water, Through Copper Coils, Cools Developer and Saves Time in Dark Room

at the College of Engineering, took 60 in. of ½-in. copper tubing and made a three-turn coil so it would fit into our developing tanks as shown in the accompanying photograph. This was connected to the cold water faucet with rubber tubing. By circulating tap water at 65° F. through this coil and moving the coil to agitate the developing solution, its temperature can be lowered from 90 to 70° F. in 5 min.

Think how much time this has saved in taking 4000 pictures during the past 10 years! (R. E. CRAMER, Special Research Asst. Prof. in Engineering Materials, University of Illinois.)

To Prevent Small Work From Sticking to Tray

HERE'S an item that is "old stuff" to veterans, but to the hundreds of new men in the heat treat it will be of some use:

When quenching small parts such as washers or nuts from a tray, the work will always

stick to the tray. To avoid this a piece of newspaper should be put on the tray first and then pile the work on the paper. When the paper burns it leaves a film beneath the work, thereby leaving it free to slide off the tray into the quench tank. (RAHL BENNING, Foreman Heat Treating Department, Supercharger Works, Allis-Chalmers Mfg. Co.)

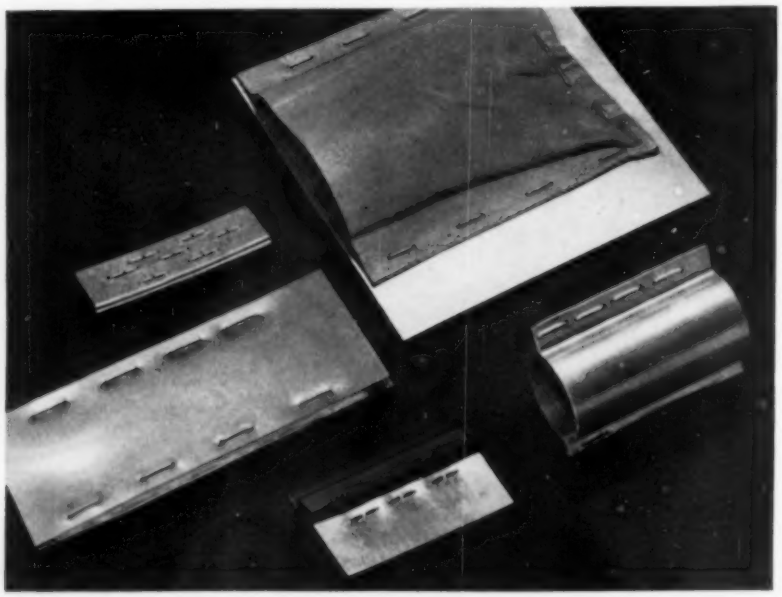
Staple It Together

WIRE stitching or stapling has been a commonplace operation in printery and bindery for generations; the hand stapler is also a standard item of desk furniture. Its recent adaptation to the needs of the aircraft industry has thrown some joining operations over into the unskilled class and saved as high as 90% of the labor cost, permitting the fastening of metals, rubber, plastics, plywood, or leather. It is recommended for unstressed parts of a plane such as heat ducts, sealing gaskets, shrouds, and map cases.

The practice depends on the use of a high carbon, galvanized wire, having a minimum tensile strength of 290,000 psi. The wire at finished size is 0.051 in., with very little tolerance permitted. The amount of zinc on the finished wire is sufficient to withstand a standard 20% salt spray test for a minimum of 300 hr.

Although the tensile strength is very high, the ductility of the wire is such that a staple can be formed through metal, with bends sharp enough for contact between the staple and material throughout the complete length of the staple.

Wire is now made to the above specifications by the writer's firm which will penetrate 0.040 in. of heat treated aluminum alloy, 0.060 in. of annealed aluminum alloy, or 0.030 in. of half-hard Type 302 stainless. It will also penetrate over 1 in. of wood. "Sandwiches" of light gage duralumin and asbestos have been made up to ¾ in. thick. (CHARLES W. MEYERS, Special Aviation Representative, American Steel & Wire Co.)



Samples Showing Applications of Aircraft Stitching Wire, Such as Three-Ply Metal, Leather on Metal, Asbestos-Metal Sandwich; Rubber on Metal, Metal to Metal Tube

Early Detection of Fatigue Cracks

WE RECENTLY were required to detect fatigue cracks in some hollow, heavy walled forgings under test, and devised a method that should work equally well on moving parts in service, without disassembling the machine:

Due to special conditions we could not remove the test piece, yet we had to detect the earliest appearance of cracks in a corner of an elbow bend. A new wrinkle to the well known oil-and-powder method solved the problem. The surfaces to be examined were in the as-forged condition, except for pickling and sand blasting. The surface was wiped clean before each examination. With the testing machine stopped, a thin, low viscosity oil was spread over the surface. Some of the oil seeped into any cracks which were present and remained there when the surface was wiped clean. Fuller's earth was then spread in a thin layer over the surface and the testing machine re-started. The oil in any cracks was forced onto the surface by the alternate closing and opening of the crack during the fatigue test and such exuded oil made a black line in the thin layer of the Fuller's earth, so the first appearance of very small cracks was easily marked.

The method can also be used to detect the presence of fatigue cracks on any exposed or visible parts in service. The part to be tested can be left right in the machine so checking for fatigue cracks can be done as often as desired for safety. No expensive equipment or material is necessary. To make a test it is necessary to stop the machine for a few minutes to prepare the surface. (GERARD H. BOSS, Chief of Metallurgical Laboratory, Glenn L. Martin Co.)

Catching Cartridge Defects at the Source

ONE of the most trying conditions met with in the manufacture of brass cartridge cases is that of surface imperfections variously described as "laminations", "surface seams", "blisters", and so on. Each case so defective must be removed to a salvage bench where the defect must be explored for depth and length by filing or hand rubbing with emery paper. If the defect appears to have appreciable depth the cartridge case must be rejected; if hand rubbing appears to eliminate it this is continued until all trace has been removed. It may be pointed out, too, that the defect must truly be removed and not just covered with flowed metal.

The above paragraph leads up to the fact that invariably when the production department runs into a cloud of these rejects the question is always asked of the metallurgical department as to why this was not noted when the raw material was received and the production people warned to look out for trouble.

Actually these defects stem from almost microscopic non-metallic inclusions, gas pockets, and blowholes, and are greatly magnified when drawn out into cartridge case sidewalls. To detect this condition in the raw material stage this laboratory has devised a test which, coupled with observations made on finished cartridge cases and on draw pieces in various stages of process, has become extremely useful.

Briefly, we subject a certain percentage of the raw material (which is received here as blanked disks) to a 180° bend test; the sample for this test is a 2-in. wide strip taken across the full cross section of the disk at the diameter, and across the direction of rolling. The sides of the specimen are then die polished on a belt sander. After bending, all surfaces are examined and inclusion bursts or any other openings are noted. Following this examination it is usual to deep etch the specimen in 50% nitric acid, which serves to accent the inclusion pits, blowholes, and other discontinuities. Experience has indicated that imperfections at the surface and extending to a depth of one-third the total thickness on either side of the disk are those which are most apt to give trouble during drawing operations.

Close watch on lots which were identified as being of poor quality by the standards of this test have substantiated this useful laboratory observation. (GEORGE J. FOSS, JR., Director, Chicago Metallurgical Laboratory, Rheem Manufacturing Co.)

Weights of Tubing

ONE day I had to calculate the weight of a lot of seamless tubing of various sizes, and had no tables to relieve me of thought. Working it out with areas of circles is a rather lengthy mathematical process, so I resorted to a simple and accurate formula which involves only the dimensions usually given for seamless tubing — outside diameter and wall thickness. There may be such a formula, but I have never seen it in a handbook, and am passing this one along, hoping it will help anyone who may have use for it. It is based on the fact that the cross-sectional area of tubing is evidently $\pi t\ (D\text{-}t)$ where D is the outside diameter and t the wall thickness. Using values for weight of metal per cu.in. gives the following in lb. per ft.

Steel tubing:	$10.55\ t\ (D\text{-}t)$
Copper tubing:	$12\ t\ (D\text{-}t)$
Aluminum tubing:	$3.58\ t\ (D\text{-}t)$

As can be seen, the formula works very easily with a slide rule. (WILLIAM H. CRAMER, Engineer, Metlab Co.)

Underwater Resistance Welding

IN EITHER soldering or brazing standard copper cable to terminals, the cable is usually stiffened by the metal, drawn into the hot cable by capillary action. This is being cured by what we call underwater resistance welding.

This process consists of welding with electrode tips of carbon, molybdenum and cupaloy. A stream of water of sufficient volume to cool the work and prevent oxidation at the weld is played on the stranded wire near the work. Machines used for this work are equipped with one fixed and one movable electrode, with a special jig fastened around the stationary terminal to hold the parts firmly in their relative positions. (Carbon tipped electrodes are used when a flux is necessary.)

The operator lowers the upper electrode to complete the weld by means of a foot pedal. The machine is air operated and timed by electronic controls; this insures a quality weld. The completed assembly may be removed immediately without the need of pliers or gloves. A typical job is as follows: 2352 strands of 0.002-in. wire were welded to copper 0.037 in. thick; time 38 cycles; current 14,400 amperes; electrode pressure 400 lb.

Jobs that were formerly performed by hand are now handled by line production. Cost has been reduced and quality and appearance of the completed parts have been improved. Cooling the

parts with water also makes handling easier and removes heat without changing the physical properties of the individual parts. (J. A. MERRYMAN, Headquarters Manufacturing, Westinghouse Electric & Mfg. Co.)

Rapid Polishing for the Duration

WHILE highest grade work on many alloys requires time-consuming methods for metallographic preparation, during these trying times when a hurried report with micrographs is often necessary it might be well to have the details of a polishing technique that is really rapid:

First, grind to a flat surface with coarse emery on a vertical wheel.

Second, remove scratches of first operation by turning specimen 90° and polishing on a wet canvas lap with No. 240El Alundum "B". Polish only until previous scratches are removed.

Third, remove scratches of second operation by again turning at 90° and polishing on a wet canvas lap with Carborundum Brand Silicon Carbide powder No. 71, 600RA. Polish only until previous scratches are removed.

Fourth, remove scratches of third operation by polishing on wet felt or velveteen using levigated alumina.

Canvas laps operate at 3000 r.p.m.; felt at 600.

Alundum powder costs 20¢ per lb.; carborundum powder, 55¢, levigated alumina costs 35¢ per lb., 11-ounce canvas costs 25¢ per yd. and velveteen costs $1.50.

In handling a class of 35 students *time* is an important factor, so the above method has been developed. The total time consumed for *all* operations should be from 3 to 4 min. Structures developed by etching alloys as polished by the rapid method exhibit the important characteristic features without distortion. Very few scratches are seen on the micrographs submitted as representative. (CHARLES Y. CLAYTON, Department of Metallurgical Engineering and Ore Dressing, Missouri School of Mines and Metallurgy.)

Inspection of Carburized Cases

THE request in "Bits & Pieces" in the May issue for inspection methods for determining quickly the case depth of parts in production, so as to be sure you are not over-casing or under-casing, brought many responses:

MARTIN SEYT calls attention to the method hinted at on page 49 of Gordon Williams' $ book "What Steel Shall I Use?" Test the hardness of the case by some light load instrument like the Monotron and then retest with a heavier loaded Brinell machine which will crush through the case and indicate an integrated hardness. Rockwell C scale (150 kg.) and Brinell (3000 kg.) make a good combination for case depths between 0.020 and 0.040 in.

JOHN M. KIEFER, Jr., Laboratory Supervisor of American Steel & Wire Co., has constructed a testing instrument for case depth (not hardness) which is used primarily on steel strip about ¼ in. thick by several inches wide. It consists essentially of a Wheatstone bridge *(Cont. on p. 120)*

Brass (75×)

Martensite (500×)

1010 Steel and Inclusion (250×)

Student's Micros, Photographed After Four-Minute Preparation

"Critical Points" in May 1941 noted that the Naval aircraft was absorbing much of a new stainless alloy — new at least in the American industry — where a little nickel is added to a 16% chromium-iron, thus giving it the ability to be quench-hardened and yet retain the superior corrosion resistance (especially in salt water) of the high chromium alloys which are inherently weak and non-hardenable. The following article describing its properties and uses is from an organization that has produced many hundreds of tons of this important alloy steel.

16-2 STAINLESS STEEL

By STANLEY P. WATKINS

Manager, Development Division, Rustless Iron & Steel Corp., Baltimore

IN THE EARLY STAGES of the development of straight chromium stainless steels of the low carbon grades, it became obvious that as the chromium content was increased above about 14%, the alloys were less responsive to hardening by heat treating operations, and were not as tough or as strong as alloys with approximately 12% chromium and the same low carbon content. This loss of hardening properties with increase in chromium could be compensated by raising the carbon, but to the detriment of corrosion resistance — particularly if the material was in the annealed condition.

Increasing chromium in these chromium-iron alloys serves to improve corrosion resistance, and in many applications it is very desirable to have an alloy with the corrosion resisting properties afforded by high chromium, coupled with high strength and great toughness. To fill this need, Brown Bayley's Steel Works, Ltd. of England, developed and introduced in 1925 an alloy which they named "Two-score". This alloy is now made in several analysis ranges within the broad limits of 0.09 to 0.30% carbon, 16 to 20% chromium and approximately 2% nickel. It was designed to have superior tensile properties to that of the low carbon, nickel-free, 16 to 20% chromium alloys and to be more suitable for resisting electrolytic corrosion when used in contact with non-ferrous metals in the presence of electrolytes, such as sea water. As shown in Chapter 12-F of ⊜'s "The Book of Stainless Steels", this type alloy is responsive to heat treatment, has good impact strength, and in general is more corrosion resistant than a similar low carbon alloy with like chromium content but without nickel.

The British Air Ministry adopted an alloy of this type and has used it extensively for structural parts on seaplanes and flying boats. This alloy is designated as S-80 and is furnished to the requirements given in Table I, in accordance with British Standards Institution specification

Table I — Specifications for Alloys

	S-80 (British Standards Institution)	AN-QQ-S-770 (U. S. Government)	
Chemical composition			
Carbon	<0.25	<0.15	
Phosphorus		<0.04	
Sulphur		<0.04	
Silicon	<0.50	0.20 to 0.60	
Manganese	<1.0	0.30 to 0.80	
Chromium	16.0 to 20.0	15.5 to 17.5	
Nickel	>1.0	1.5 to 2.5	
Tensile properties		Class I*	Class II†
Ultimate	>123,200	>175,000	>115,000
Yield (0.2% set)		>135,000	> 90,000
Elongation in 2 in.	>15%	>13	>15
Izod impact	>25 ft-lb.	>35	>60
Brinell hardness	>241		

*Hardened and tempered. †Annealed.

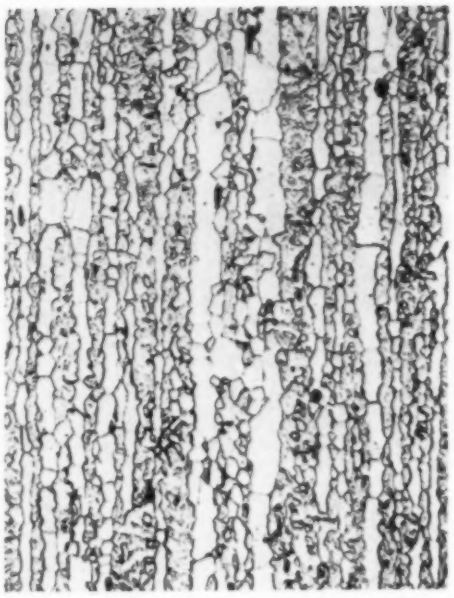


Fig. 1 — Structure of Quenched Low Carbon 16% Chromium-Iron (Low Nickel) Showing Much Ferrite and Little Martensite. Longitudinal section of bar, magnified 200 diameters. Brinell 250

for this material. During 1942 a large tonnage of S-80, principally in the form of billets and bars, has been produced in this country for shipment abroad, most of it in the analysis range of 0.10 to 0.15% carbon, 16.0 to 17.0% chromium and 1.5 to 2.0% nickel.

The "Twoscore" type of alloy, popularly known as "16-2" in this country, was never produced in quantity in America until 1941. The reason for this is not clear, as the properties of the alloy were generally known to the trade. One reason perhaps is that this type of stainless steel is not as easily produced as some of the other grades, and therefore has not appealed to any American producer. In addition, 16-2 is not as amenable to cold forming and welding operations as the 18-8 and 17% chromium grades which are so popular in this country.

The greater proportion of 16-2 produced for domestic use has been made to conform with Army-Navy Aeronautical Specification AN-QQ-S-770 of which the essential requirements are also given in Table I.

In addition to the tabulated requirements, the alloy must be of aircraft quality as regards cleanliness, and in the hardened and tempered condition resist pitting and corrosion when subjected to 24-hr. continuous salt spray, in accordance with the standard Navy test.

As a matter of convenience the stainless steels are classified into three broad groups — martensitic, ferritic and austenitic — depending upon their structural nature and response to heat treatment. 16-2 falls in the martensitic group, as it responds to hardening by quenching, and its structure in the quenched condition is largely martensitic. The microstructure of hardened 16-2 (carbon about 0.15%) also contains areas of free ferrite which impart a laminated appearance. In material which has received plastic deformation, the ferritic areas are generally elongated in the direction of maximum work, and this imparts directional properties to the material.

A chromium-iron containing about 0.15% carbon and 16% chromium is essentially of the

Fig. 2 to 4 — Structure of Low Carbon 16% Chromium, 2% Nickel Alloy, Magnified 200 Diameters

Fig. 2 — Longitudinal section has stringers of ferrite when quenched. Hardness 364 Brinell

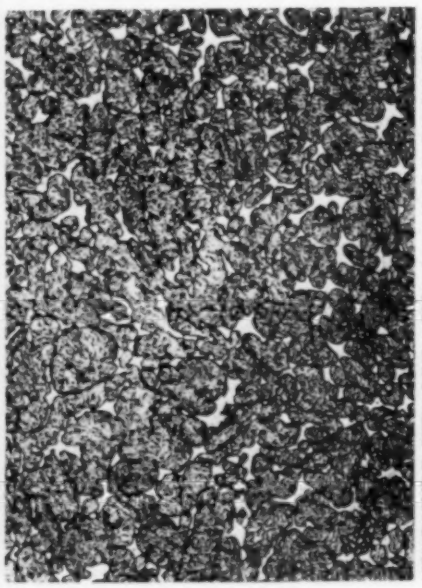


Fig. 3 — Transverse section cuts across the ferrite stringers

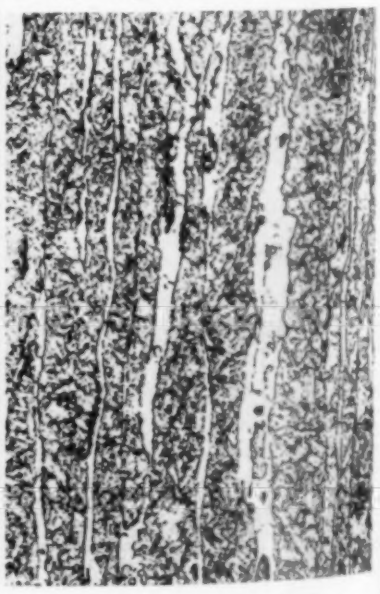
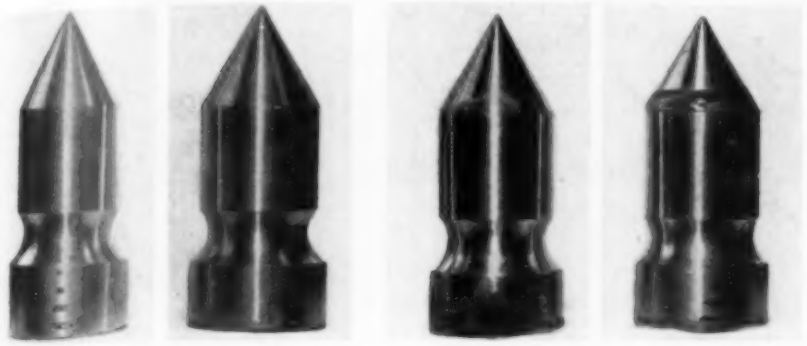


Fig. 4 — Annealed structure, longitudinal section. Hardness 241 Brinell

Fig. 5 and 6 — Corrosion Test Pieces



Annealed Hardened Hardened Annealed

Fig. 5 — 500 hr., running tap water Fig. 6 — 100 hr., 4% salt spray

ferritic type and when heated into the normal quenching range there exists a duplex structure of a little austenite and a great deal of stable ferrite. Quenching or rapid cooling, therefore, produces a predominant ferritic structure with only a small amount of martensite (Fig. 1). The maximum hardness, when quenched, barely reaches 300 Brinell.

The addition of about 2% nickel to this alloy increases considerably the amount of austenite formed at elevated temperatures. Consequently, when an alloy of this composition is cooled rapidly, as in air or oil, the austenite formed at elevated temperatures largely transforms into martensite which hardens the steel. However, the analysis of 16-2 is such that it does not *wholly* transform to austenite when heated to above its critical range, so a good deal of free ferrite remains in the hardened structure. Nevertheless, the total martensite formed in 16-2 is much greater than in the nickel-free alloy, as shown in the adjoining micros, and this results in increased hardenability, toughness and tensile strength.

The effect of increasing amounts of nickel in lowering the critical range on heating results in increasing the viscosity of the alloy during transformation, which in turn decreases the speed of transformation. (Reaction rates are normally much slower at low temperatures than at high temperatures due to decrease in atomic mobility with decrease in temperature.) Due to the low critical cooling rate of 16-2 it cannot be annealed by slow cooling from above the critical temperature and hence cannot be softened to as low hardness as a similar alloy without nickel. Also, it is necessary to heat considerably above the upper critical range to obtain full transformation in a reasonable period of time and to effect maximum hardening on quenching.

In general, the corrosion resistance of 16-2 is slightly superior to a straight chromium alloy of equal chromium content, but cannot be considered the equal of 18% chromium, 8% nickel alloy in resisting most corroding mediums. However, under conditions involving exposure to salt spray, tap water, steam, food products and fruit juices, 16-2 compares very favorably with 18-8. In kind with all the martensitic stainless steels, 16-2 exhibits its maximum corrosion resistance when in the fully hardened and drawn condition.

In salt spray and tap water tests, as shown by Fig. 5 and 6, 16-2 shows perfect resistance to tap water (500 hr.) and is only slightly corroded in the salt spray (100 hr.). In the salt spray test, hardened 16-2 shows somewhat better resistance than annealed material; in fact 16-2 compares favorably with 18-8, but has a greater propensity towards pitting, particularly if exposure to salt spray is extended to periods of 500 hr. or more.

As pointed out in a previous paragraph, the

addition of about 2% nickel to a 16% chromium alloy serves to produce a stronger, harder and tougher stainless steel which is amenable to heat treatment. In common with other heat treatable stainless steels, a range of tensile properties can be obtained in 16-2 by hardening, followed by tempering treatments.

Experience has shown that the most favorable hardening cycle is to heat within the range of 1900 to 1950° F. and soak for approximately 30 min., then quench in oil or cool in air. This treatment will result in an average hardness of 387 Brinell. (A typical range of tensile values obtained by hardening and tempering is given in Table II.)

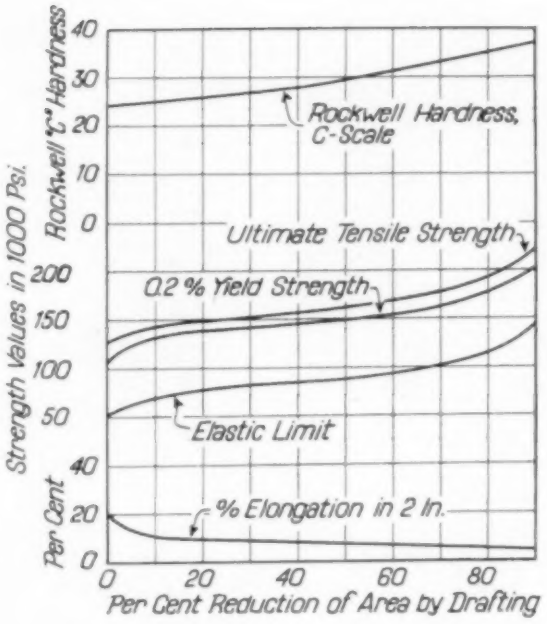


Fig. 7 — Effect of Cold Drafting on Properties of Annealed 16-2 Wire

Sluggish Anneal

Owing to the sluggish reactions within the alloy at heat treating temperatures, 16-2 does not respond to annealing treatments as readily as the other hardenable grades of stainless steel, as it is very difficult to soften the alloy below about 240 Brinell by commercial annealing practice — heating to just below the Ac_1 point (1150 to 1250° F.), and holding for several hours.

The Izod impact properties of 16-2 at subzero temperatures, down to —40° F., is excellent, showing values averaging above 35 ft-lb. for material having an ultimate tensile strength of above 175,000 psi.

Owing to its air hardening characteristics, 16-2 is not as suitable for welding as the 18-8 or 17% straight chromium (low carbon) grades of stainless steel which have little or no tendency to harden during welding operations. However, in electric arc or gas welding, it is possible to weld 16-2 successfully if an 18-8 electrode is used, the parts preheated to about 750° F. and welded at this temperature. After welding, the entire assembly should be annealed by heating in the range of 1150 to 1250° F. for 1 to 2 hr.

Like all the stainless steels, 16-2 is stronger and harder at forging temperatures than ordinary steel, and consequently requires more power and heavier equipment to form. It is necessary to preheat bars and billets carefully to the range of 1400 to 1600° F., and then heat fairly rapidly to the forging heat: 2150 to 2200° F., and begin working when the metal has attained full heat throughout. Work should not be done below about 1700° F., and if metal has cooled below this temperature before forging is completed, it should be reheated. Due to the intense air hardening characteristics of this grade, forgings should be slowly cooled from the hammer heat, otherwise thermal cracking may result. The most satisfactory method is to bury the hot piece in an insulating material. If forgings are large, cooling in a closed container is generally satisfactory.

Table II — Physical Properties of Heat Treated 16-2

Heat Treatment				Tensile Properties				Izod Impact	Brinell Hardness
Heat (°F.)	Quench	Reheat (°F.)	Cool	Ultimate Strength	Yield (0.2% Set)	Elong. in 2 in.	Reduction		
1925	Oil	..	..	200,000	125,000	8.0	40.0	10	395
1925	Oil	400	Air	180,000	130,000	17.0	50.0	45	360
1925	Oil	750	Air	175,000	125,000	17.0	55.0	50	350
1925	Oil	1150	Air	125,000	95,000	20.0	55.0	50	250

The hardness and tensile properties of 16-2 can be increased somewhat by cold deformation, as shown by Fig. 7. However, the high hardness of this alloy when "dead soft annealed" militates against good cold working properties, and if the material is severely cold worked, as by drawing or rolling, it is very desirable to relieve the internal strains by heating at 750 to 850° F. for

several hours. The ductility of fully annealed 16-2 permits simple cold upsetting operations, but it is not considered suitable for such cold upsetting and extruding operations as are commonly used in making bolts and screws.

Machinability

Recognizing some four years ago that the data then available on the best methods for machining and cutting stainless steel were not adequate in many respects, the Rustless Iron and Steel Corp. inaugurated a research program for determining the most favorable conditions for machining these alloys. This involved an investigation of tool grinds, cutting speeds in relation to tool life, cutting

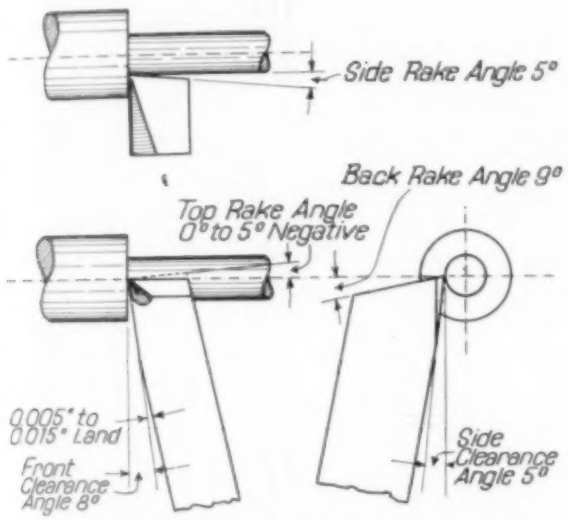


Fig. 8 — Chip Curler Type of Tool and Set-Up Recommended for Turning Stainless Steel

oils, and factors affecting surface finish as well as the metallurgical phases such as hardness and structural conditions of stock. Since then a great deal of the data accumulated in the laboratory has been applied to set-ups in consumers' plants; in most cases the correlation has been excellent and has led to more efficient production. The data given below on the machining of 16-2 were obtained in this way, and have been modified in collaboration with users who are machining this alloy on a production basis.

In common with all the stainless steels, 16-2 is more difficult to machine than ordinary steel, success depending to a great extent upon proper tooling and machine set-up. To secure best results on 16-2, cutting tools should be made of a good grade of high speed steel, properly heat treated and ground. Some suggested tool shapes are shown in the sketches.

In turning operations, the best results are obtained by using a chip curler grind on cutting tools as shown in Fig. 8. The same principle

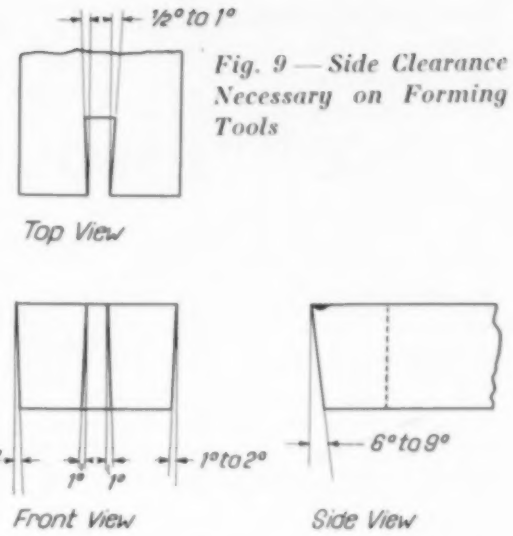


Fig. 9 — Side Clearance Necessary on Forming Tools

can be applied to forming tools, as shown by Fig. 9, above.

Cutting speeds which have been found most satisfactory for 16-2 in the annealed or cold drawn condition are shown in the list below. They are of necessity approximate, as so many factors affect machining rates that an absolute rate for a given operation cannot be set; however, they do serve to indicate the range of speeds in which 16-2 can be successfully machined. Maximum machining rates are attained only when proper cutting oils are used in conjunction with favorable tool set-ups. Experience has shown that a sulphurized oil mixed with paraffin oil to the proportion of about 4 to 1 yields satisfactory results for most machining operations.

Surface Cutting Speeds for 16-2 in Ft. per Min.

Operation	Speed	Type of Tool and Grind
Box turning	80 to 100	10 to 15° top rake or chip curler
Finish turning	80 to 100	10 to 15° top rake and 1 to 2° side rake
Forming	70 to 90	10° rake grind, 2° side clearance
Threading	10 to 20	10 to 15° rake or hook grind; 20 to 25° tangent or circular type
Drilling	20 to 40	130° included angle
Tapping	5 to 15	Hook or rake grind
Reaming	10 to 30	Spiral flute type 30° chamfer lead
Milling	25 to 40	Spiral type, 10 to 15° tooth rake

The author wishes to express appreciation for the assistance given him by other staff members of the Rustless Iron and Steel Corp. in assembling data for this article. George Stevens supplied the machining data, W. C. Clarke prepared the photomicrographs, and I. C. Clingan the corrosion data.

CORRESPONDENCE

and FOREIGN LETTERS

Test for General Corrosion Not Adequate for Intergranular Attack

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

As a result of wartime postal delays I have only just received the copies of *Metal Progress* issued during the last quarter of 1942. One article in the October issue particularly attracted my attention, first by its title, "Huey Corrosion test for '18-8' Steel", and later by its contents.

The authors of this (which is an abstract of a translation of a pre-War Belgian article) spoke of 18-10 steels containing 0.25, 0.50, and 0.70% carbon respectively, which were "homogeneous and austenitic" after quenching in water from 2100° F. This must have been an error, for the maximum solubility of carbon in 18-8 steel at this temperature, as determined by Bain and Aborn, is about 0.3%. They also suggested that these steels were only "slightly weakened at the grain boundaries" by heating for an hour at 1100° F., whereas they would, of course, be extremely susceptible to intergranular corrosion after such a treatment.

One gathers that in order to get such a result the European authors depended on their experiments wherein samples were exposed to boiling 67% nitric acid for three periods of 24 hr. each (as in the Huey test), and then the losses in weight were measured. They, no doubt, regarded a rate of corrosion of not more than 0.004 in. per month (or something of that order) under these conditions as indicating a satisfactory structural condition in the steel.

Now, whether one should use Huey's reagent (67% nitric acid) or the acid copper sulphate solution generally used in Britain, or some other corrosive liquor for detecting susceptibility to intergranular attack is a matter of personal opinion. My choice is the acid copper sulphate solution because it possesses two features which appear to be supremely important: It has no attack at all on a properly heat treated 18-8 steel, but rapidly attacks one which is susceptible as a result of faulty heat treatment. Good results could also probably be obtained with any corrosive reagent which will preferentially attack the susceptible grain boundary material, but what possible significance can the *rate of attack* quoted above (0.004 in. per month) have in regard to *intergranular* corrosion?

It is well known that the results of corrosion tests are frequently based on loss of weight, and the effects of time. The size of the test sample is taken into account by calculating this loss in terms of unit area and time — for example, grams per square meter per hour. The implied assumption of constancy of attack over the whole surface of the sample during the whole time it is exposed to the corroding medium may be taken a stage further by calculating, from the known density of the metal, the thickness of the presumed uniform layer which would be removed in the course of some specified time, say a year.

Such derived figures are often of considerable value as they provide an easily visualized measure of the intensity of the corrosive action. It must always be realized, however, that they are theoretical values founded on the *assumed* constancy of attack. If the attack is not uniform over the surface or its rate not constant during the whole period of the test, the value so calculated may be altogether misleading.

Whatever views may be held as to the causes of intergranular attack, everyone will agree that it does not occur uniformly over the attacked surface. In fact, it is hardly possible to imagine a greater departure from uniformity than an attack which removes a very thin layer from the grain

boundaries of a metal and leaves by far the greater part of each grain absolutely unattacked. Unless all of these loosened but practically unattacked grains are removed from the surface by abrasion or some other means, the loss in weight of an attacked sample is insignificant compared with the depth to which intergranular attack has penetrated. Moreover, it does not and cannot give a reliable indication of this depth. This is particularly the case with a reagent like 67% HNO_3, which has an appreciable attack on properly heat treated 18-8 steels, and one which varies in degree with their chromium contents.

It seems surprising that loss in weight figures should ever be suggested as a criterion of the extent of intergranular corrosion. It seems simpler and so much more satisfying to bend a test specimen through 90° or so after it has been exposed to the selected corroding liquor. Then the attacked boundaries of a susceptible sample part company, and the bent surface shows obvious cracks and fissures. Even simpler — just drop the sample on the table; a damaged metal is easily distinguishable by the dull, lead-like sound given after it has suffered intergranular attack.

A very good idea can also be obtained, sufficient for most practical purposes, of the depth to which intergranular attack has penetrated by visual examination of a bent sample. If a more accurate measure of the depth of the attack should be required, or of the rate at which it has taken place, the very elegant method described by Aborn and Rutherford of measuring its electrical resistance is surely all that could be desired.

J. H. G. Monypenny
Metallurgist
Brown, Bayley's Steel Works, Ltd.

Minimizing Hardening Strains

Phillipsburg, N. J.

To the Readers of Metal Progress:

I was much interested in the Editor's description of the "hot quenching" (see "Critical Points" for January), which enabled a machinery maker to substitute NE8620, a low alloy steel, for a fairly high alloy "Krupp analysis". In this practice the lightly carburized part was quenched in hot salt, held 8 hr., cooled in air, and used without a draw. One can presume that this practice is equivalent to "austempering", explained and patented by the U. S. Steel Corp. Research Laboratory, wherein the hot steel — austenite — is quenched rapidly past the "nose of the S-curve" (past 1000° F. in say 5 sec.) down into a region where austenite is relatively stable, so stable in fact that in this particular case its transformation requires time on the order of 8 hr. Even such a long holding time will probably not cause all of the austenite to transform; the remainder will transform into martensite as the piece cools from the salt bath.

Such extremely long times of holding in the salt bath will scare off the practical man, with a production schedule to meet. The scientist will also recognize that the result of this slow transformation of austenite at a constant temperature is not hard martensite, but another softer metallic constituent termed "bainite", whose properties are as yet not too well known.

We at Ingersoll-Rand Co. have adopted a modified and much speedier practice which has helped us cut down on rejects from heat cracks. It involves an accurate time quench in a medium that is chosen with relation to the size of the part and its chemical analysis, so that the metal even at its center is safely past the nose of the S-curve at 1000° F. without any transformation of austenite into fine pearlite. Once this is effected the metal is immediately placed into a salt bath to equalize at a temperature just above that where martensite starts to form (the top of the Ar″ range for that particular steel), and held there long enough so the temperature becomes thoroughly equalized. Austenite is so stable at this temperature that none of it transforms. Then when this piece is removed from the salt and cooled in air, transformation of the austenite to martensite will occur. Such a practice will minimize the residual stresses and strains, inseparable with any quenching process, set up by three unavoidable circumstances: *(a)* the steel contracts as it cools, *(b)* it expands when changing from austenite to martensite, and *(c)* these changes occur at different times at different places since the surface is cooler than the center.

I have coined the term "martempering" to describe this operation of hardening by cooling quickly to just above Ar″, equalizing the temperature, and cooling slowly through the Ar″ range, thus producing hard martensite. It is distinctly different from the "austempering" process, which definitely avoids the production of martensite by a much longer stay in the salt bath at temperatures considerably above Ar″.

This temperature, the top of the Ar″ range, may be called the martensite point and abbreviated as Ms. I predict that in the near future, the determination of this point will be as essential a part of steel data as the critical points and hardenability are at present.

Benjamin F. Shepherd
Chief Metallurgist
Ingersoll-Rand Co.

Good Penetration at High Welding Rates

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

In the correspondence pages of *Metal Progress* during the turn of the year, an interchange of opinions was recorded on the advantages (and supposed disadvantages) of a larger-than-ordinary welding electrode. The last word was given by A. B. White who said:

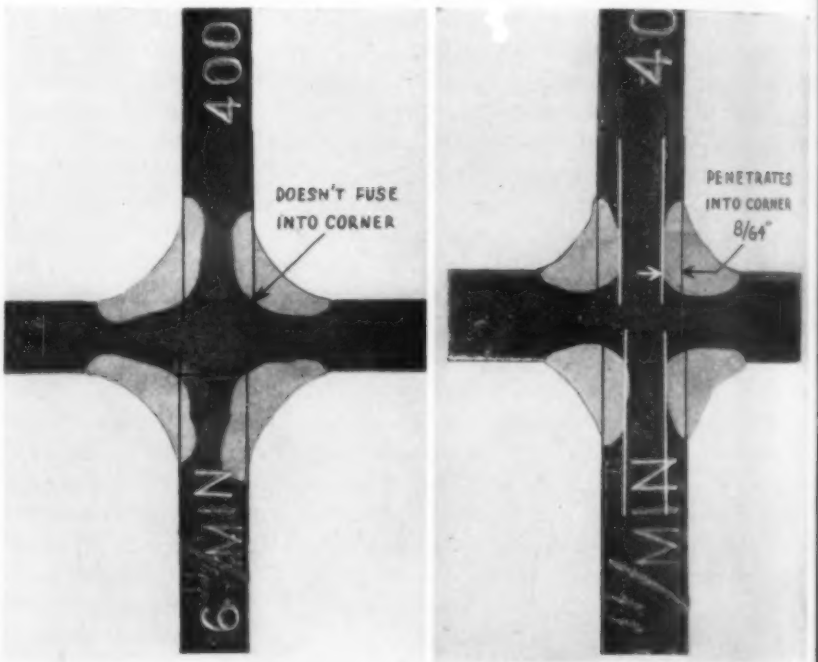
"For the same size of weld, an increase in length proportional to the electrode consumption may be obtained by larger electrodes, but it may be accompanied by an increase in undercutting and porosity, and a decrease in the all-important root penetration. Reducing the weld speed will reduce the tendency towards undercutting and poor root penetration, but this practice defeats the advantages of using larger electrodes."

May I put on record our experience that this is not a correct statement to make of really modern electrodes and welding processes. It is our experience that there is actually less tendency for undercut and porosity using large electrodes, high speeds and currents than there used to be with slow speeds, small electrodes and low currents.

The statement that reducing the welding speed will reduce the tendency of poor root penetration is also wrong, as of 1943. Actually, an increase in welding speed increases root penetration. Conversely, a decrease in welding speed decreases root penetration. This is shown in the two figures alongside. The joints shown were welded with the same electrode carrying the same current, 400 amperes. The arc speed in the first case was 6 in. per min. The welds in the second were made with exactly the same procedure, except the arc speed was 12 in. per min. As can be seen, the weld made at 12 in. per min. penetrated into the root by ⅛ in., whereas the one made at 6 in. per min. did not penetrate into the corner at all.

This same condition will hold true with any size or type of shielded arc electrode, providing the currents used are within the recommended range, and providing the arc speeds are within reasonable limits — the "reasonable limit" being between the lowest speed at which a good appearing weld can be made, and the highest speed at which a good appearing weld can be made. This range is normally from 5 to 15 in. per min.

As is evident by looking at the two figures, more weld metal was piled onto the outside of the joint at the lower speed. However, the effective throat and the strength of the joint were not increased, for the lesser amount of metal deposited at higher speed was compensated for by the penetration into the root.



Arc Speed: 6 In. per Min. Arc Speed: 12 In. per Min.

Representative Fillet Welds Made With ¼-In. "Fleetweld No. 11" Electrode, Current 400 Amperes

Therefore, instead of high speed being a detriment, it becomes an advantage. There will be less distortion due to less deposited metal. One-half as much electrode is used and only one-half the time is required to make the joint.

In concluding, I would like to say that many applications are being welded with the proper size of electrode at present, and the number is increasing every day. However, if all operators who are not using a large enough electrode were to use the proper electrode and technique, there would be a large increase in the average welding output per man.

L. K. STRINGHAM
Welding Application Engineer
Lincoln Electric Co.

Machinability of Metals

SOMEWHERE IN FRANCE

To the Readers of METAL PROGRESS:

Two complex factors are involved in machining of metals, each one partially a function of the other:

1. "Machinability" of the material.

2. Cutting capacity or value of the tool.

From the first systematic studies of machining of metals, made by F. W. Taylor, were derived, first, rules of machining which defined the geometric and mechanical conditions of operation (such as the influence of the form of the tool, angle and depth of cut, feed, speed, lubrication, cooling), and second, the use of high speed steels containing considerable tungsten. These empirical studies, however, merely reproduced a standardized operation and determined principally the length of time before the tool was rendered unfit for further service. Thus, no information was given on the properties of the material involved in the operation, which might help predict to a certain extent the machinability and cutting power. In fact, considerable care was exercised to see that the steel being cut was uniform in its nature.

At the present time it seems possible to analyze the phenomena more exactly by means of criteria corresponding to less complex and more elementary properties of the material. Machinability appears to be conditioned by the following factors:

1. The hardness of the material in relation to that of the tool. For instance, quenched steel and white cast iron are not machinable (in the true sense) by ordinary toolsteels. For a series of materials of similar properties, machinability (U) can often be calculated from the hardness (Δ). An example is the formula given by Melle for gray cast irons:

$$U\,\Delta^{1.47} = 10{,}000.$$

On the other hand, materials of similar hardness can have widely differing machinability — for instance, mild steels (ferritic) and high nickel steels (austenitic). This is because their deforming and cold working properties are very different.

2. Herbert associates machinability to hardness after cold work, or, more exactly, to the hardness which the material can attain by means of cold work. Expressed in other words, this involves the true rupture strength, which depends on the hardness (Δ) or the tensile strength (R), as well as the capacity for deformation before rupture, which can be expressed by the elongation (A) or reduction of area (Σ).

Thus, materials of low capacity for deformation before rupture, such as gray cast irons, are easy to machine under conditions producing short chips. Following this lead, the machinability can be increased by diminishing the ductility, particularly transversely, since the tool generally moves normal to the fibers of the metal. This is one of the reasons for the ease of machining the high sulphur screw stock. Moderate cold work, which decreases the ductility without raising the hardness excessively, improves machinability. Inversely, austenites with high elongation, which harden rapidly by cold work, have poor machinability; austenite with 25 to 30% nickel is difficult to machine and austenite with 12% manganese is practically unmachinable by carbon toolsteels.

Janitzky has defined this influence by demonstrating that for steels the cutting speed V_{60}, which corresponds to a time of 60 min. for a standard tool, can be related to Δ and Σ by a relationship such as $\frac{K}{\Delta^m\,\Sigma^{(m-n)}}$; for instance, $\frac{K}{\Delta^{1.63}\,\Sigma^{1.01}}$ for a feed and depth of cut of 1 and 6 mm. respectively. [This relation is utilized by Mr. Meagley in the leading article in this issue.]

3. The force exerted by the tool, or cutting force, which can now be determined and measured during the cut by various methods such as dynamometric, hydraulic, electrostatic, electromagnetic, and electrolytic — and notably by the use of a piezo-electric quartz, a sensitive process free from inertia. This cutting force is related to the deformation and form of the chip. Also to be considered is the friction of the chip on the working face of the tool — a factor which must not be neglected, as we shall see.

The work involved in machining a metal is transformed into heat which is dissipated by conduction into the work-piece and the tool, and by heating the chip as well as the coolant, if any be used. Thus, there is established at the point of the tool an equilibrium temperature which will furnish us a new criterion of machinability since it depends on the effective work for given conditions of cutting.

4. This working temperature (Θ) at the point of the tool can be determined by means of a thermocouple placed near the point (which is rather difficult), or by making use of the couple formed by the tool and the metal machined, as practiced by various investigators.

This last mentioned criterion appears to be particularly interesting, since it establishes a bond between the machinability of the metal, defined by this temperature, and the cutting power of the tool. The latter is limited by the temperature at which the metal of the tool softens

(tempering temperature for martensitic tool-steels) or oxidizes (in the case of hard carbides). Furthermore, there should be, according to Schallbroch and Schaumann, a relation between the cutting time T and the working temperature Θ:

$\Theta T^{1/m} = C$ (m and C being constants).

To cite a recent example, Peters has found a difference in machining temperature of about 60° C. between steels containing 0.10 to 0.15% lead and the same steels without lead, machined under the same conditions. This lowering of the machining temperature caused by the presence of lead can be demonstrated by a simple experiment: A bar is made by welding end to end two sections of the same diameter, one of leaded steel and the other of the same steel without lead. This bar is machined under cutting conditions such that the chips formed by the steel without lead appear at a blue heat; when the leaded steel is reached, the chips are not colored.

Since the general mechanical characteristics of the ordinary leaded steels are little different from those of the same steels without lead, it can be considered that the cold work (Herbert's criterion) is the same in both cases, and that consequently the variation in temperature should result largely from the difference in friction of the metal on the tool, lead playing its classic role of lubricating the metal, or rendering it self-lubricating.

On this same subject it might be remarked that the frictional properties of industrial alloys in actual use are provided either by the presence of lead (lead bronzes, babbitt or other anti-friction alloys) or by the presence of graphite (gray cast irons, graphitic copper). Similar means should permit us to improve machinability as well. In fact, machinability *has* been improved by means of graphite for ferrous alloys (gray and malleable cast iron, graphitic steels) and by means of lead for copper alloys (brasses for cutting) and even for aluminum alloys. The process developed by Inland Steel Co. for incorporation of lead permits us to extend this method to steels. (Generally, non-abrasive inclusions, such as porosity and blowholes, can also improve machinability, and the presence of inclusions can "orient" machinability, the metal no longer being isotropic in regard to this property.)

Another method of increasing machinability is by structural and mechanical heterogeneity. The present writer has shown in his book, "Introduction to the Heat Treatment of Metallurgical Products", that to improve machinability of steels after heat treatment, the treatment should produce a mixture of two different constituents, as by an incomplete quench to ferrite and martensite, or by an imperfect quench to troostite and martensite. It should be remembered that this treatment for ready machinability may not produce optimum load-carrying properties.

On the other hand, the presence in the metal to be machined of very hard mineral constituents, such as inclusions of alumina, silica and acid silicates, can abrade the working face of the tool and cut down drastically the number of pieces per grind.

Finally, in the study of machinability another criterion which must not be forgotten is the nature of the machined surface. This last factor has incited a vast amount of work on methods for surface examination, which are too numerous to consider here but which enable us to define the machining finish and to determine its influence on the properties of metallic parts more exactly than by visual examination.

Thus, the examination of these complex criteria or properties, which themselves depend on numerous circumstances in the manufacture, composition, heat treatment and mechanical treatment of an alloy, provides order, clarity and simplicity in the study of machinability.

ALBERT M. PORTEVIN
Consulting Engineer
Bessemer Medalist

Dowgtite in Steel Castings

WATERVLIET, N. Y.

To the Readers of METAL PROGRESS:

Dog lovers among you might appreciate this enclosed photomicrograph at 300 diameters. The animal was recently observed in a manganese-

molybdenum steel casting. Positively no retouching was exercised, and we have tentatively christened this pooch structure "dowgtite".

WILLIAM KAHLBAUM
Metallurgist
Watervliet Arsenal

High Carbon in 18-8 Ti

BEAVER FALLS, PA.

To the Readers of METAL PROGRESS:

Could I, at this time, comment on a letter from F. H. Keating published in *Metal Progress* for January, wherein he cites the large use for chemical plant in England of 18-8 Ti with 0.16% max. carbon?

Perhaps American manufacturers are unduly restricted with respect to carbon content in the stabilized austenitic 18-8 alloys, inasmuch as present specifications, as exemplified by ASTM A167-42 and A240-42, for sheet, strip and plate, specify a limit of 0.10% max. carbon. In the columbium alloy, the columbium must be not less than eight times carbon content, and titanium not less than four times the carbon content in the titanium alloy. It was previously shown by Bain and co-workers that theoretically not less than four times carbon content in titanium should be employed for stabilization; consequently if the proper ratios between carbon and the stabilizing elements are employed there is no real reason why the carbon content should not be increased, as is done in British practice. This would certainly be helpful in view of the present scrap situation.

On the other hand, it has been found that excessive amounts of columbium and titanium which would be required by the higher carbon content give rise to reaction products which interfere with surface quality, and these are particularly detrimental in tube manufacture using cold drawing processes. American procedure is therefore a compromise which keeps the carbon content down to a somewhat lower level so that smaller amounts of the stabilizing elements need be introduced into the bath.

While we do not know how the inspection standards compare between our practice and British practice, we would be reticent about going to the higher carbon material unless we were assured that the surface condition found on the manufactured articles would be commercially usable. We may be forced to move up the carbon content in our stabilized austenitic steels, but at present writing the emergency alternate provisions of standard specifications limit carbon content to 0.10% maximum.

Material required for welding and for ordinary purposes is now quite comparable in composition, as you will note from perusal of the reference specifications given above.

H. D. NEWELL
Chief Metallurgist
The Babcock & Wilcox Tube Co.

Keep Cutting Fluids Clean

FOSTORIA, OHIO

To the Readers of METAL PROGRESS:

Writing for the April issue of *Metal Progress*, Joseph Geschelin, Chairman of the Independent Research Committee on Cutting Fluids, has said that a change in cutting fluids on an established set-up may increase production from two to ten times, and may make the difference between a fine finish and a poor one.

In this statement of fact are the two real objectives of a precision grinding department. Thus, any procedure which looks like it may make a genuine contribution to better and faster production has the attention of those in charge of grinding operations. This explains why more and more attention is being given to cutting fluid selection, why the trend has been for some time toward fitting the coolant to the particular job in precision grinding. It is no longer accepted as good practice to count on one type of cutting fluid — supplied by a central system — to do an efficient job on a multiplicity of grinding operations throughout the shop.

To keep a cutting fluid at top efficiency, of course, requires that it be substantially free of dirt, sludge, grit and other foreign particles when it reaches the cutting wheel. In this connection, The Carborundum Co. has this to say about clean cutting fluids:

"In recent years there has been an increasing tendency to rely on specially constructed wheels for many difficult grinding jobs. Many operations warrant such special consideration, but in numerous cases the work could be done just as well and more economically with a standard wheel properly cared for.

"It is a generally accepted fact that a good job of cutting and grinding cannot be accomplished unless the grinding wheel is kept clean. The dressing of the wheel from time to time is, of course, essential, but the importance of clean grinding coolants cannot be emphasized too strongly."

Keeping coolants clean is a matter of proper filtration, removing the foreign particles from the fluid, so it reaches the grinding wheel in a clean stream. Where several different types of fluids are used, this means localized filtering, of course, because a central system cannot handle more than one type at a time.

No less an authority than the Norton Co. expresses this opinion: "Experience has shown that their (localized filtering machines) use helps to keep the wheel face clean and free-cutting and reduces wheel truing. They are especially helpful when fine grit wheels are employed

on both grinding and lapping machines for producing fine finishes free from scratches which result from dirty coolant."

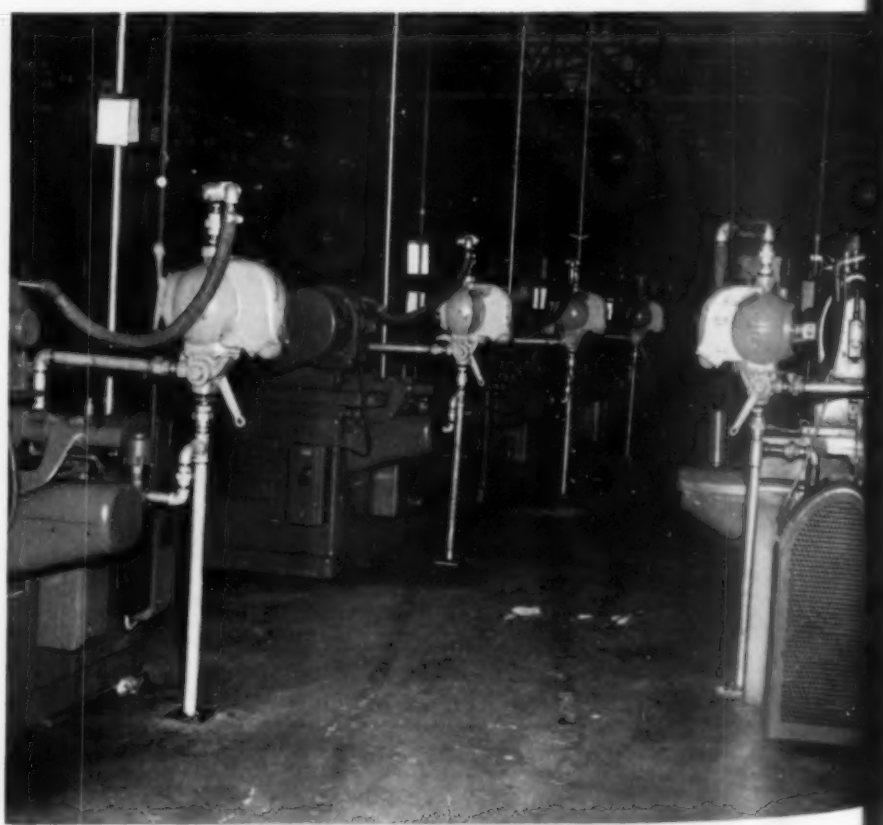
E. F. Houghton Co., cutting fluid manufacturer, says, "It is an established fact that the minute fragments which are removed from the piece being ground should not be allowed to continue to circulate through the system, as they detract from the efficiency of the grinding solution. It is therefore important that close attention be paid to the proper filtration of these metallic fragments from the grinding solution in order to obtain the highest degree of efficiency. The most practical method of doing this is by passing the coolant through a filter before it reaches the grinding wheel."

Wright Aeronautical Corp. enjoys the honor of speeding production of their famous aircraft engines to an unprecedented record. Realizing that the goal can be attained only with good workmanship and top performance of tools, production engineers at Wright have equipped all their grinding machines with localized filtering units, as the accompanying photo of a section of the grinding department shows.

Records at the Wright plant show that spoilage is at a minimum, production is speeded, finishes are improved, wheel dressings are less frequent and wheel life is extended by the use of clean cutting oils.

Failure to keep cutting fluid free from abrasives is an expensive oversight, because it means *(a)* heavily clogged wheels and dull cutting edges, *(b)* more frequent wheel dressings with the attendant waste of wheels in the dressing operation, *(c)* scratches on the work requiring additional passes to remove these marks, *(d)* decreased production due to time needed to clean up the "fish-tails" and other imperfections on the surface of the work, *(e)* unsanitary working conditions, because dirty coolant is an excellent breeding ground for skin disease germs.

PAUL H. KRUPP
Fostoria Pressed Steel Corp.



View Down One Aisle in Wright Aeronautical Corp., Showing Individual Coolant Filters at Each Grinder

DESPITE a doubled capacity for electric steel, estimates made early in 1942 indicated that production of such steel (reserved for aircraft and engine parts, armor, and bearing steels) would be approximately 60% of the requirements in that year. New facilities for another million tons of ingot capacity were authorized, but by mid-1942 it was apparent that completion would be delayed from lack of necessary materials and equipment. In view of the ever-increasing requirements, further expansion was later ordered by the War Production Board, and Donald M. Nelson's year-end statement hopefully anticipated the total electric furnace capacity by June 1943 to be 6,153,000 tons of ingot, just about four times the capacity of the entire industry in 1939.

Ever since Pearl Harbor there has been a much greater demand for our product than we could supply. It is likely that this condition will persist until the last enemy surrenders. It is therefore obvious that every effort should be made to increase production from the existing furnaces. Some suggestions toward that end will be made in what follows, based on some notes presented orally at one of the War Production

INCREASING THE YIELD OF ELECTRIC FURNACES

By HARRY F. WALTHER
Asst. Superintendent of Melting, Timken Steel & Tube Division, Canton, O.

Sessions at last year's ⚙ convention. While the problem of minimizing down-time between heats will be emphasized, other important factors in maintaining high steel production rates will be mentioned.

It is rather difficult to generalize when discussing electric furnace operations, since furnaces range in size from one ton to 100 tons, may be either basic or acid, and produce a great variety of products including castings, toolsteels and specialties (which are generally produced in the smaller furnaces) and quality alloy steels from the larger furnaces. The adoption of furnaces of over 25 tons capacity has been comparatively recent. The few large furnaces which have been operated from 1927 have proved that more production of many alloy steels could and should be made in the larger units with greater economy and no sacrifice in quality.

In order to minimize down-time between heats there are several factors which warrant discussion. While it is true that a sizable part of the tonnage is made by the duplex process (openhearth to electric) and the triplex process (blast furnace to converter to electric) the greater amount now requires a 100% cold scrap charge. An important fact to consider is that *alloy* scrap may be selected and melted with a minimum loss by oxidation of chromium, manganese and vanadium — all critical elements which must be conserved. It therefore is good practice to divert all scrap possible containing these elements to the electric furnace.

A good scrap burden for expeditious handling, charging and melting consists of approximately 35% heavy crops, 40% medium scrap, and 25% fairly light scrap such as flashings, bundles, briquetted turnings and that cosmopolitan type called "low phosphorus". This charge is seldom available in the proper proportion; the industry is burdened with too much light scrap of inferior grade. So one of the first and most acute problems connected with electric steel production revolves about the supply of cold metal. The goal for electric steel in 1943 is about 5,500,000 tons and in order to approach this figure the following aspects may be considered:

1. About 25,000 tons per month of heavy and medium mill scrap, which would ordinarily be melted in the openhearth, must be diverted to electric furnaces, in trade for much unsatisfactory scrap the electric furnaces are now using.

2. Originally, low phosphorus plate was clean and of proper chemical and physical requirements. Now, No. 1 and No. 2 busheling and No. 2 heavy scrap in large amounts are found mixed with good, clean material. Realizing that the scrap situation is tight and that all kinds must be used, it is necessary that all types of the lighter scrap be segregated *at the source* into the proper classification, and thus permit the steel melters to select and use it to the best advantage.

3. Washing, briquetting and roasting medium and low carbon turnings at the source is found to be very advantageous at several large plants, and the practice should be greatly extended. Properly prepared briquettes are one of the finest types of scrap for electric furnace use. Since so many of the turnings of this type are being produced which are difficult to handle

in the loose, oily state, it is almost mandatory that greater effort be made in this direction. Valuable oils are also recovered.

4. In melting the higher carbon steels, up to 10% of the initial charge may be low silicon pig iron. If some casts of the lowest phosphorus and sulphur content in this grade could be earmarked for the electric furnace, another metal-mix advantage would be provided.

(The net result of the above outlined scrap program would result in very much shorter periods of charging in both door-charge and top-charge furnaces, with attendant economies and greater production.)

5. Increasing the size of door openings permits the use of larger charge boxes and will speed up charging from 15 to 20%. This is important to the larger furnaces handling heavier scrap.

6. Door arches and jambs must be so designed that the brickwork is not damaged in charging. During periods of continuous operation, magnesite linings are justified in the basic furnace. However, magnesite arches and jambs have poor structural strength and are a source of delay between heats because of necessary repairs. Much of this may be avoided by installing water-cooled arches directly back of the door frame to supplant one course of brickwork. This arrangement supports the whole arch and jamb and is very efficient when serviced adequately.

7. To eliminate bottom patching delays it is necessary that new bottoms be properly installed. The most satisfactory basic bottom is one in which the sub-hearth is built to the desired contour with magnesite brick, over which is rammed high magnesia refractory such as "Ramix" to a depth of 7 or 8 in. (less in the smaller furnaces), the hearth being insulated adjacent to the shell. As much as 50% in time is saved by this method over the practice of burning-in. If the brickwork is set up and sealed in such a manner that crevices are avoided, the whole bottom becomes a monolith through which metal or slag rarely penetrates deep enough to cause damage, thus requiring less servicing after the tap.

8. Wherever possible, hand-charge furnaces should be replaced by top-charge devices, to conserve labor and speed up production. This applies mainly to old units under 6 tons capacity. The problem of relative performance between top-charge and side-charge in the large furnace class remains somewhat of a moot question. However, most of the recent installations of 50 tons or over have been the door-charge type. The problem is one of fitting the unit to the plant layout.

The major part of the electric output goes into the most critical of armament applications in which inferior steel cannot be tolerated. Our offensive program revolves around the ability of this industry to produce in ever greater quantity and at no sacrifice in inherent quality. Therefore, in supplying proper metal-mixes and promoting changes in furnace design and maintenance, down-time between heats may be minimized, production increased, and melting procedure simplified. Prior rating in raw materials will always be necessary to keep the electric furnaces melting at the highest rate.

WILLIAM HUNT EISENMAN, Jr.
Second Lieutenant, U. S. Air Force
March 11, 1921—May 28, 1943

"We looked upon your photograph, and thought—is this our son?
Of all the dreams we had for you, somehow this wasn't one—
That you should be in uniform, a Soldier of our Land,
And yet we never were so proud, we hope you understand"
(—Hilda Butler Farr.)

FIRED CARTRIDGE CASES

(Continued from page 74)

and B (with 60% fired cases); a possible explanation for this may lie in the fact that the hardening effect is practically confined to the skin of the bar. After testing for season cracking, all the drawn bars showed a fine network of cracks, the extent being similar for each.

After reeling no cracking was visible in any of the samples made with fired cases. No difference in machinability could be detected.

Microscopic examination, both before and after etching, at magnifications up to 500X, revealed no essential difference between the mixtures made from normal materials and those containing cartridge cases, and no traces of an antimony constituent were visible.

In summary:

1. Antimony is the deleterious element introduced into brasses by the use of fired cartridge cases.

2. A marked difference in color was observed in fractures of alloys made with cartridge cases as compared with those made from usual materials, except in the case of naval brass. This peculiar color has been reproduced by adding a similar percentage of antimony to an alloy made entirely from virgin metals.

3. Approximately 0.01% antimony is introduced by the use of 60% of fired cartridge cases.

4. No difference has been observed between the effect of clean fired and muffled cases.

5. The use of fired cartridge cases should be avoided in straight copper-zinc alpha-beta brasses, especially 62:38, as they have a definite embrittling effect, the properties of resistance to shock and cold riveting being most detrimentally affected.

6. The deleterious effect on the 62:38 brass has been reproduced by adding antimony to an alloy of the same composition made from virgin metals.

7. It is estimated that 10 to 20% of cases can safely be used in leaded brasses with very slight impairment of properties, provided no other antimony-bearing material is used in the mixture.

8. At least 40% can be used in melting 62:37:1 naval brasses.

9. A brass rod for forging, made with 30% of cases, was tested with satisfactory results for the production of fuses.

10. The effect of antimony on cold drawn 2% leaded brass is similar to its effect on "as extruded" material.

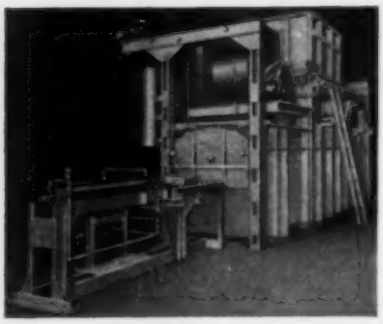
11. The susceptibility of leaded brasses to season cracking is not increased by the use of cartridge cases in the mixture.

12. Elongation of leaded brass rods is drastically reduced by the presence of 0.02 to 0.10% antimony.

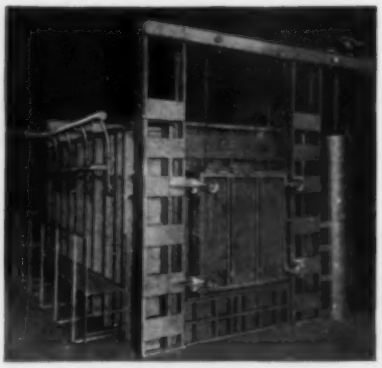
13. No detrimental effect of antimony has been noted on the hot working properties or machinability of any of the copper alloys investigated.

JOHNSTON FURNACES

A TYPE FOR EVERY HEAT TREATING PURPOSE



4'-0" x 27'-0" x 2'-0" Recirculating Roller Rail Pusher Type Draw Furnace



54" Dia. x 55 Ton Ingot Heating Furnace

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Lindberg
LINDBERG ENGINEERING COMPANY
2450 West Hubbard Street Chicago 12, Illinois
ARMY
NAVY

THE FUTURE AUTOMOBILE

(Continued from page 71)

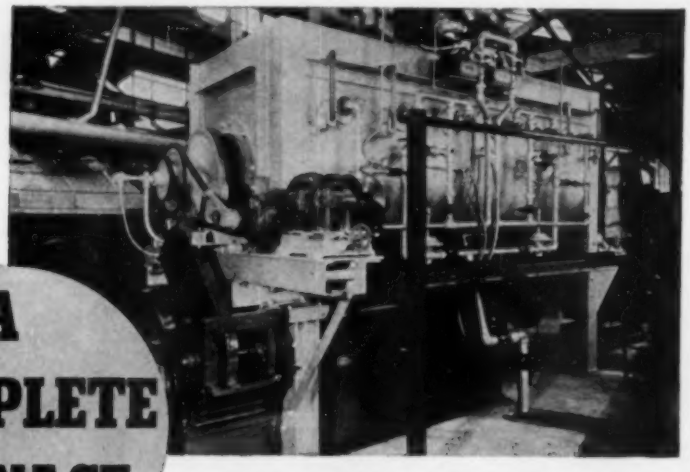
foolproof, and it may be recollected that the stresses in an airframe are reasonably calculable; moreover, it operates in a resilient medium. A road vehicle, on the other hand, is subject to unpredictable impact stresses arising from its operation on an inflexible surface. (It is noteworthy that the undercarriage, which permits the aircraft to function as a wheeled vehicle during takeoff and after landing, is mainly a steel structure.) In any case, excessive lightness of the smaller classes of road vehicle is not a particularly desirable aim, owing to the suspension problems introduced by the wide difference between the unladen and the gross load condition.

"It is only a step from light alloys to plastics, and here again it is a popular theme to predict the 'plastic car'. This is to place the plastics industry in danger from its over-optimistic friends. Before plastic material can wisely be adopted for large components an easy means of repair must be evolved. As a means of quantity production molded plastics offer great scope, but the engineer should protect the public from low-priced but almost unrepairable articles.

"But if there is no reasonable justification for beguiling the public into accepting the conception of the road vehicle of the future as being something on the lines of an aircraft fuselage, it must not be overlooked that in aero accessory equipment there is much that could usefully be adopted. Special multi-pole plug and socket connectors used in the complicated electrical wiring come especially to mind. No one who has tried to deal with the rear connections of an instrument panel needs convincing that this would be a genuine forward step. For heavy vehicles also, the very efficient high pressure pumps serving hydraulic actuations appear to be equally applicable to control and brake mechanism.

"In all these things the automobile engineer has a considerable duty to the public, to the car owner, and to the vehicle operator. Vast strides in technological development are being taken in all directions. Much is applicable to road vehicles, much is not. It is unfortunate that some items of the latter sort appeal to those who insist upon being linked with all that is latest, whether it be desirable or otherwise.

"To develop the road vehicle wisely and not merely as a commodity to be sold; to help in an escape from that vicious system of building the ephemeral; to check wanton wastage of raw material; and to restore to the craftsman his self-respect is the contribution which the engineer can make toward the shaping of the better things to come."



A COMPLETE FURNACE . . . IN OPERATION . . . IN CONTROL

This Rockwell Rotary Heat Treating Furnace (Rotary Type) is COMPLETE in two respects . . . (1) it takes care of every operation, including charging, washing, heat-treating, pickling, drying and discharging; and (2) it is fully automatic in control of temperature, time and rate of heating.

ROCKWELL SINCE 1888 BUILT

The result . . . each individual unit of product is uniformly heat-treated, in the shortest time, with minimum labor. This is why war-industry plants all over the country have chosen Rockwell Furnaces to assure maximum production of quality products.

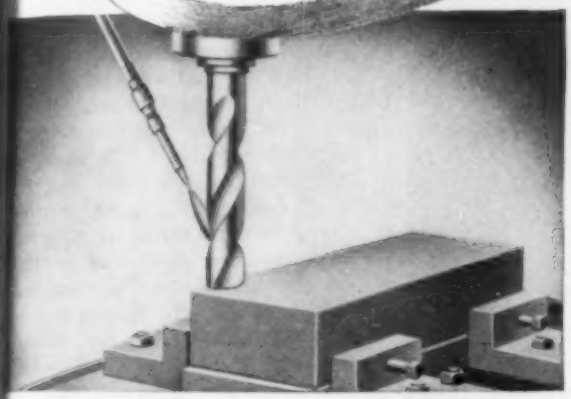
If your production involves heat-treating operations, be sure to investigate Rockwell Furnaces. Write for Catalog 3973.

7-43

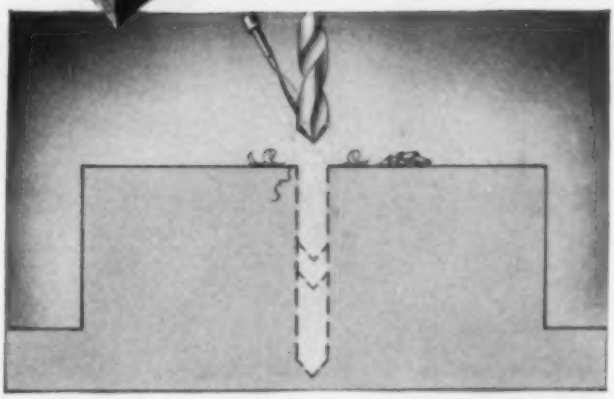
W. S. ROCKWELL CO., 50 Church Street, New York

ROCKWELL
ROTARY HEAT TREATING FURNACE
(RETORT TYPE)

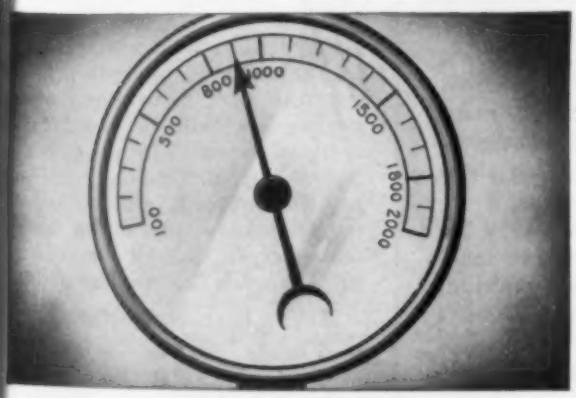
Helpful Hints for Drilling Tough Steel



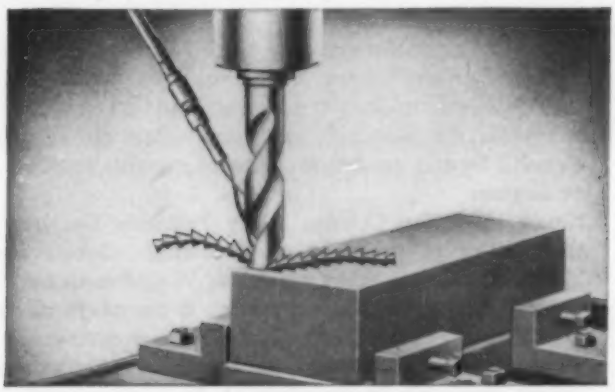
1. Use steady pressure and do not let drill ride without cutting. Back out the drill frequently to relieve chip congestion.



2. Back out when the drill has reached a depth three to four times the diameter of the drill for first insertion—one to two for second insertion—three to four for third.



3. To avoid drill breakage, always run at the proper speed. A 1/16" center drill should run about 1800 r.p.m. (30 s.f.m.). A 1" drill at 115 r.p.m. for same surface speed.



4. For deep drilling use a short spiral drill and Chillo No. 140 or 143, cut back with Amplex No. 00, further to reduce high temperatures. For shallow drilling use Chillo No. 90 or 93.

5. If you are faced with an unusual machining operation or if you are not satisfied with present results, call in a Cities Service lubrication engineer for consultation. His experience with Cities Service precision-made cutting oils on all kinds of machining operations is certain to help you as it has others. There is no obligation. For a copy of an informative booklet, "Metal Cutting Lubrication," write to Cities Service Oil Company, Room 1657, Sixty Wall Tower, New York 5, N. Y.

OIL IS AMMUNITION— USE IT WISELY!

CITIES SERVICE OIL COMPANY
NEW YORK · CHICAGO

ARKANSAS FUEL OIL COMPANY
SHREVEPORT, LA.

INSPECTION

(Continued from page 98)

circuit attached to 110-volt a.c. power, and having two air-gap reactors with steel cores located in two of the arms of the bridge circuit. A galvanometer determines when the circuit is balanced, through the use of rectifiers on each side of it. One of the air-gap reactors is located in the measuring head, and is attached to the main body of the instrument by a flexible electrical cord. (A ready-made instrument of this type can be had from the General Electric Co., developed to measure the thickness of non-magnetic coatings on magnetic base metals.)

Procedure is as follows: Begin by making three or four carburized samples with varying case depths, checked microscopically. It is essential that these calibration samples be cooled in the same manner as the production to be checked for case depth. The instrument is calibrated by placing a non-magnetic layer of material of constant thickness, such as onion skin paper 0.001 to 0.002 in. thick, between the piece to be calibrated or to be checked and the measuring head of the machine. Samples to be tested are handled in exactly the same way.

The deflection of the galvanometer indicates the depth of the carburized case. Accuracy is not extremely great, but is sufficient to ascertain the *uniformity* of work carburized in batch lots. Pieces too lightly or non-uniformly carburized can thus be determined and retreated and reclaimed. Work can be either in the unhardened or in the hardened condition, but hardened gives the best results.

OWEN W. ELLIS of Ontario Research Foundation reminds readers of *Metal Progress* that the device originated by P. E. Cavanagh and described in the September 1942 issue can readily measure differences in case depth by comparing their induced magnetism to that of known standards. An improved model called the Magnetoscope is now being made by Allen B. DuMont Laboratories of Passaic, N. J., and Mr. Cavanagh states that whereas the instrument has been very successful in sorting mixed parts, and has intriguing possibilities in routine inspection, there is not yet enough experience with the machine on carburized work to make definite statements as to its proper field of use. He believes that the high frequency testing instruments will be found to be best, on account of the well-known fact that high frequency currents hug the surface layers, and has submitted photographs of the oscilloscope screen showing the accuracy in testing ½-in. rounds of 1020:

TIME	CASE DEPTH	INDICATION
1 hr.	0.010 in.	14 units
2 hr.	0.017 in.	22 units
3 hr.	0.028 in.	31 units

RICHARD C. WYNNE of Anacostia Naval Research Laboratory also calls attention to "a good, fast, production-line check for hardness and depth of case" by Frank Dedek's "Penetor" made by Magnetic Products Corp. of Detroit, and described in *Instruments* for January 1941. This instrument compares the unknown against a standard by measuring the reluctance of the magnetic paths induced in them by standard fields. As many as 1800 measurements an hour can be accurately taken.

A *Complete* ALLOY CASTING SERVICE

Production of alloy steel castings is a fussy job...requiring extremely close control over each step in the process. Raw materials are checked against rigid specifications...moisture content of sand is precisely controlled...pouring temperatures are closely regulated. Result? Sound castings...free of cracks, surface defects, cold shuts or seams.

Since 1922 The Cooper Alloy Foundry Co. has specialized in the production of stainless steel, monel, nickel, chrome-iron, chrome-nickel and other alloy castings. We offer users of castings resistant to corrosion, heat and abrasion, a complete alloy casting service... production "know-how" plus practical assistance in the selection of proper alloys. You can get sound castings from Cooper that are "right" for your application.

THE *Only* ALLOY FOUNDRY WITH *All* THESE FACILITIES

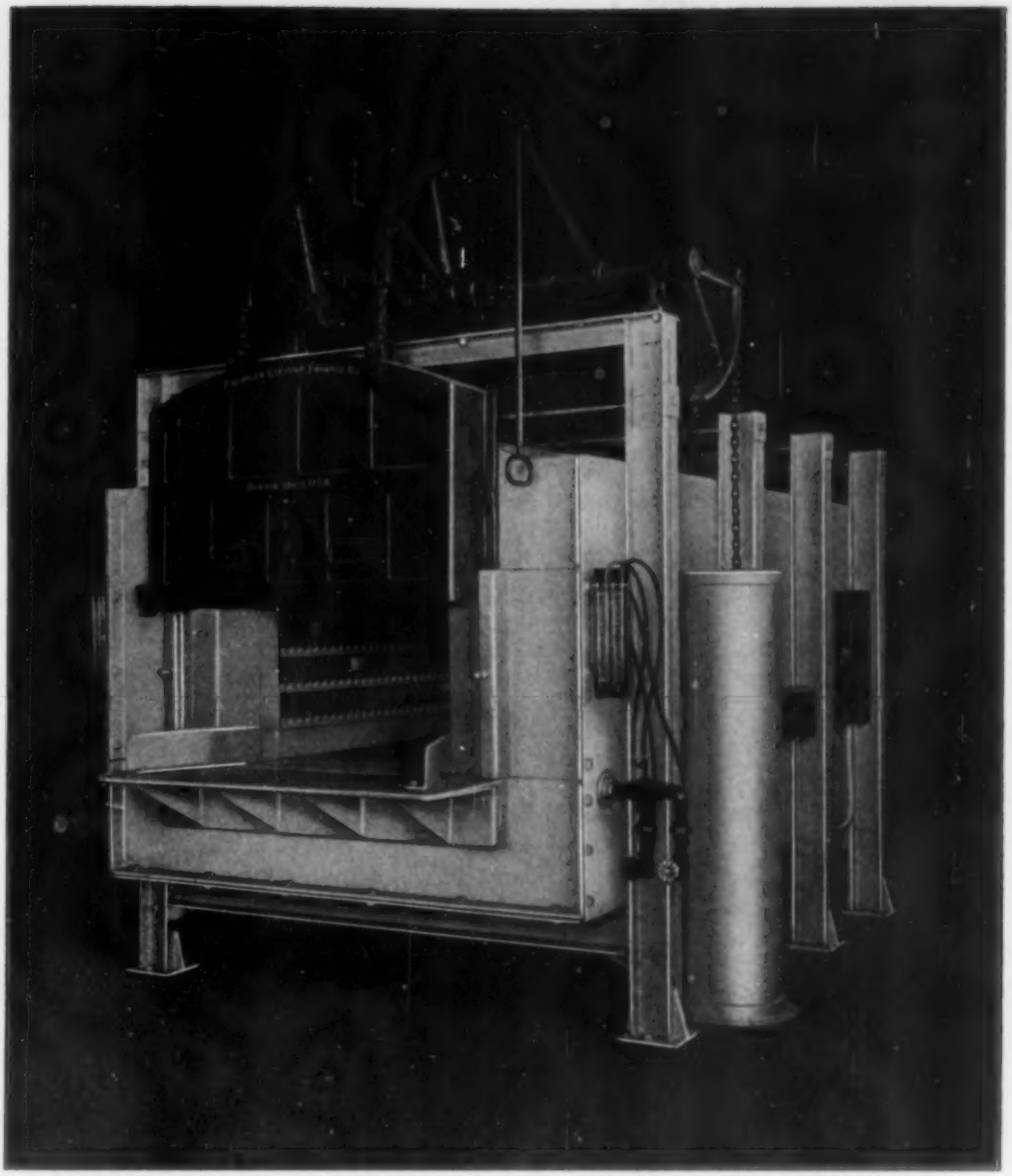
- Laboratory control over raw materials and finished products.
- Dual foundry...both hand and machine molding.
- Heat treating of castings up to six feet in size.
- Machine shop . . . specially equipped for finishing stainless steel.
- Improved cleaning . . . including Lustracast electrolytic finishing which leaves all surfaces bright.
- Castings furnished rough, polished or fully machined . . . one ounce to two tons.
- Development of special alloys to meet unusual requirements.
- Technical consulting service.

THE *Cooper* ALLOY FOUNDRY CO.
115 BLOY STREET • HILLSIDE, NEW JERSEY

Look!

at several
before you
buy

but be sure
you get these
features



Model B4884. Capacity 1000 lbs. per hour at 1500° F. Working space 48" w x 84" d x 22" h.

Built in 20 different sizes.

Check List

Shell—Reinforced steel, non-warping.
Lining—Preburned shapes, tongued and grooved.
Arch—Preburned shapes, lap joints.
Hearth—SiC, nonwarping, high heat conductor, 70% supported.
Insulation—Composite brick, thru seams eliminated.
Door—C. I. insulated, self aligning, lock seal.
Atmosphere Control—Gases forced through narrow slot at door filling work chamber and enveloping work.

AEF

American Electric Furnace Company

30 VON HILLERN ST. ★ BOSTON, MASS., U. S. A.

Industrial Furnaces for All Purposes

NEW PRODUCTS

Vernier Angle Gage

The Clinometer, a vernier angle gage, has been introduced by Engis Equipment Co., 310 S. Michigan Ave., Chicago, for use wherever angles and inclinations have to be checked. Gage may be used to test setups in the inspection room. Special models are furnished for testing airplane propeller blades, ship propellers, and templates.

Electronic Heaters

A line of electronic heaters for high frequency induction heating of metal parts for brazing, soldering, and selective heat treatment has been announced by General Electric Co. Essentially these are power oscillators which convert 60-cycle power to high frequency power (approximately 500,000 cycles per sec.). They are available in two standard sizes — one having an output of 5 kw. and the other an output of 15 kw.

Ampac "200" Welder

An important forward step in alternating current welding, in the form of new Ampac "200" welder, is announced by Allis-Chalmers Mfg. Co., Milwaukee. Described as the welder with the ideal operating curves, this new machine automatically gives the operator the correct voltage for the continuous range of currents available, rather than using an almost constant voltage at all current settings. This adjustment not only makes welding easy at low currents because of the high striking voltage, but saves power when welding at high currents because the voltage is low.

Alternating-Current Welders

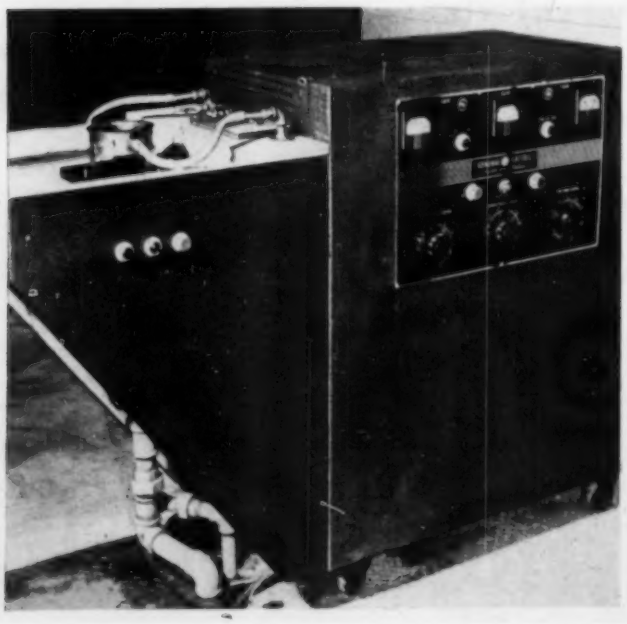
With a view to expanding the value of its welding equipment to war industries, Harnischfeger Corp., Milwaukee, has added a complete line of industrial A.C. arc welders to its present extensive line of D.C. machines. The new line features the recently adopted "WSR" (Welding Service Range) ratings, which show the actual minimum-to-maximum output of usable welding current.

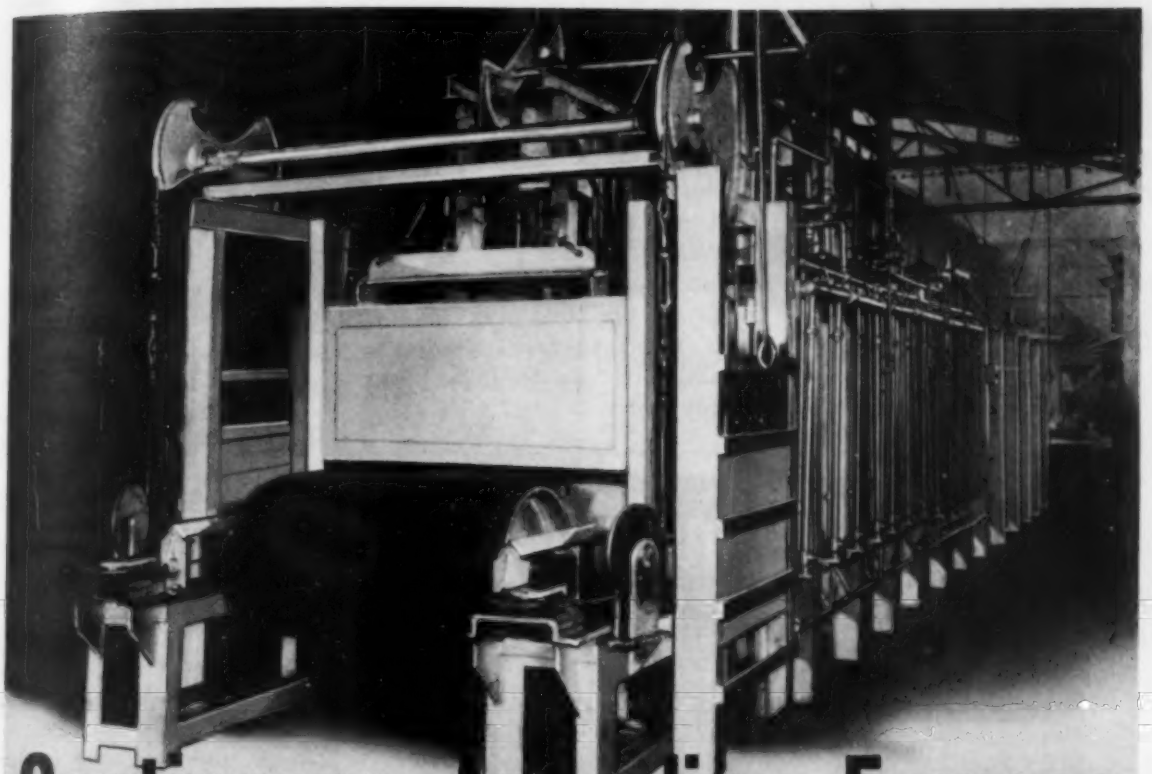
Setting and control of current throughout complete welding service range involves one simple adjustment, easy to operate. Improvements in the control are said to make it creep-proof. The company has also introduced a new all-position electrode, especially for use with A.C. transformer welding machines.

Tocco Heated Bomb Casings

Combination of an automatically controlled spinner and Tocco induction heating enables the Wheeling Steel Corp. to shape 250 and 500-lb. high explosive bomb casings in just two operations, in contrast to other methods which require as many as

(Continued on page 148)





Continuous Annealing Furnace

Being one of varied types we build for special problems in Annealing. Shown here is furnace equipped with woven chrome nickel belt which can be replaced with conveyor chain suitable for handling heavy parts. Construction is sturdy and ample for maximum capacity. Heat is automatically controlled and speed of belt is variable. Due to controlled cooling cycle, this furnace is especially adapted to N. E. manganese steels.

HEAT TREATING FURNACES for

Carburizing
Normalizing
Hardening
Tempering
Cyaniding
Stress Relieving
Atmosphere Control
Naturaliding
Brazing

LANSING FURNACES
FOR INDUSTRIAL HEAT TREATING

Owing to the highly specialized demands for this type of equipment, we are prepared to confer with you in your own plant. Ask for our point-of-use engineering service.

LANSING ENGINEERING CO. 1043 EAST GRAND RIVER AVE. EAST LANSING, MICHIGAN

NEW PRODUCTS

(Continued from page 146)

ten steps with reheats before the final shape of the bomb is achieved. Further, the induction process is a novel method of heating for the working of steel by steel mills.

In a battery of 200-kw., 3000-cycle, Tocco Jr. induction machines, equipped with inductors (designed by the Ohio Crankshaft Co., Cleveland), the short pieces of heavy steel pipe are heated first for the shaping of the nose and then for the tail. Spinning follows each heating. Elapsed time for these two operations on the 500-lb. bomb does not exceed 14 min., while the smaller bomb is finished considerably faster.

BETTER PRODUCTION
BETTER CASTINGS...

Detroit furnaces are used for triplexing, duplexing, or cold melting any desired number of hours per day on large heats or small. Versatile, flexible and fast melting, these furnaces insure highest quality metallurgical results under accurate control. They save labor, metal, fuel and time. Their inherent economy is further enhanced by their frequent use of salvage materials such as borings, turnings and other scrap. Write today for further facts and prices.

DETROIT ELECTRIC FURNACE DIVISION
KUHLMAN ELECTRIC COMPANY • BAY CITY, MICHIGAN

Toolsteel Simplified

Ways and means of getting faster tooling and improved tool performance are set forth in "Toolsteel Simplified", by Frank R. Palmer, vice-president of the Carpenter Steel Co. Here are 313 pages of plain, practical, common sense that will help you make tools last longer, help you get more production from present equipment. Priced at $1, the book is available for distribution in the U.S.A. from the Carpenter Steel Co., Reading, Pa.

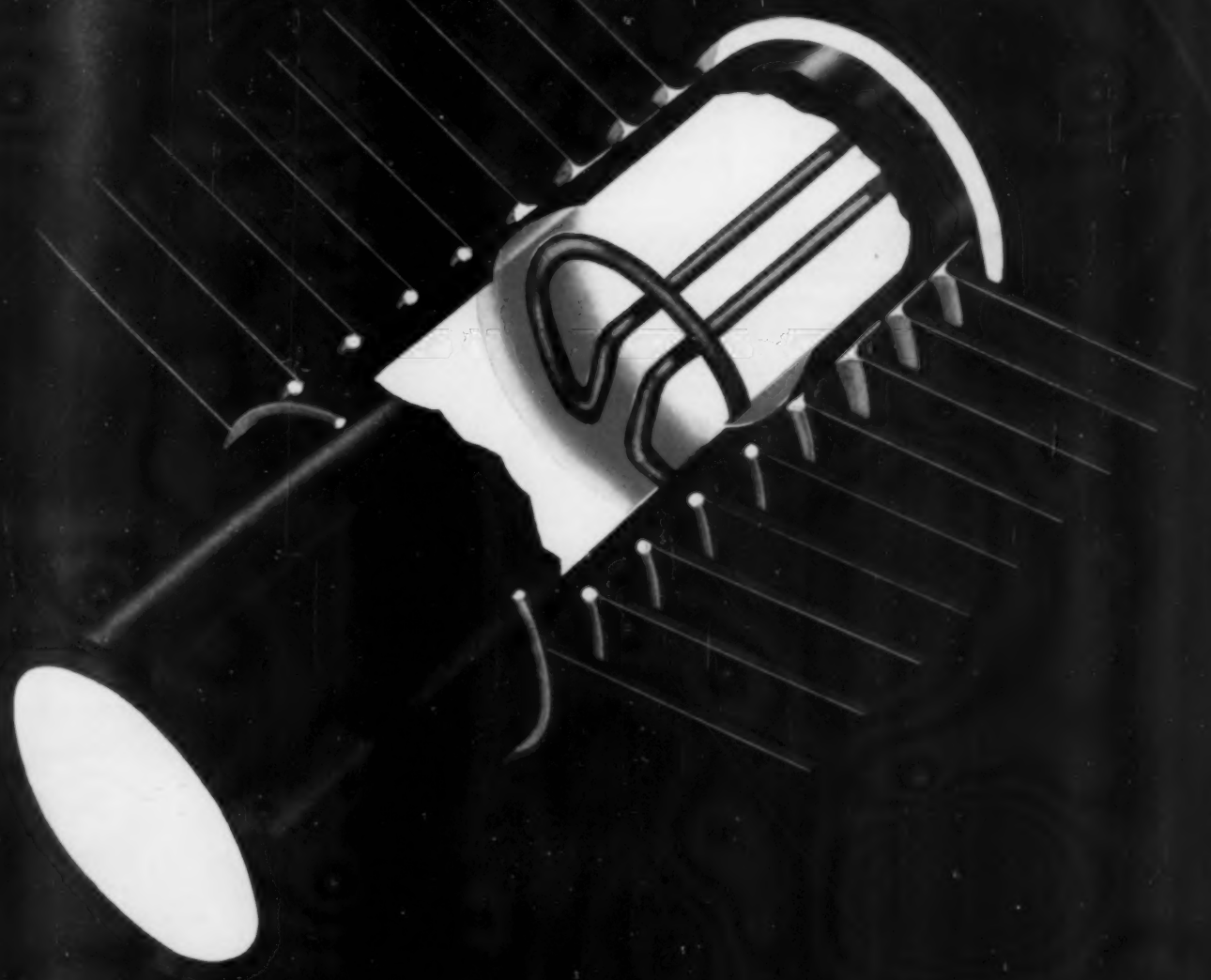
Washer for Assembled Engines

Another Howard development is a cabinet-type cleaning machine to speed aircraft engines on the production line. This machine, made by Howard Engineering & Mfg. Co. of Cincinnati, is 13 ft. high, and the sump is sunk 4 ft. below floor level to conserve space and facilitate loading. Uniform cleaning is obtained by a turntable holding engine and assembly stand. Turntable revolves at 4 to 6 rpm. to wash, rinse and dry one engine com-

pletely in about 20 min. All solutions are handled through one set of spray pipes pointing in all directions around the engine and its stand. First wash water, then rinse water, is pumped on the engine parts, after which heated high-velocity air is ejected through the blow-off nozzle, to carry away excess water from the engine surfaces.

THERMONIC

The Most Efficient and Economical System for Induction Heating



the inside story of a tough brazing job

One of the more difficult brazing jobs has been that of multiple fins encompassing a hollow cylindrical core . . . the heat required for the braze frequently distorting the fins. Induction Heating's solution to the problem is to wind wire solder around the fluxed core so that it lies against the joints formed by core and fins . . . and simply pass a coil through the cylinder. As the coil passes through, it heats the cylinder by induction, and this, in turn, heats each fin by conduction, forming a perfect, clean braze without affecting the body of the fin in any way.

Simple? Yes—after you know how! Most of the tougher brazing, melting, surface hardening, forging or annealing jobs can readily and economically be performed by unskilled workers using our highly adaptable "Thermonic" equipment. Heat is localized exactly where required and operating cycles are cut to a matter of seconds . . . a real saving in time, labor and current costs. Our power-tube generators are the most efficient ever designed for this purpose.

Whgtever your particular heat-treating problem, our technical staff can and will help you. Call them in . . . and learn how progressive plants of every kind are achieving high-speed, uniform production with this most modern method.

Induction Heating Data Sheets are available for you upon request

INDUCTION HEATING CORPORATION

Largest Producers of Electronic Heat Treating Equipment for

389 LAFAYETTE STREET, NEW YORK, N. Y.

- brazing
- melting
- surface hardening
- forging
- annealing

NEW PRODUCTS

Tool Room Furnace

New bench type furnace for the tool room is offered by Harold E. Trent Co., Philadelphia. Furnace is heated electrically, and can be controlled either manually or automatically. Heating elements are the Trent folded and formed, nickel-chromium, ribbon units.

Steel Containers

Steel containers for high pressure gases and liquids, designed and produced by Walter Kidde & Co., Belleville, N. J., have recently been made available for general use on lower priorities. Made of alloy steel, cylindrical in shape with round bottoms, they are necked and threaded to specification and have working pressures up to 1800 psi.

Identometer

The Identometer, an electrical instrument for identifying instantly — by the use of reference specimens — any ferrous alloy, is now manufactured by the American Tubular Elevator Co. and distributed by the Dravo Corp., Pittsburgh, Pa.

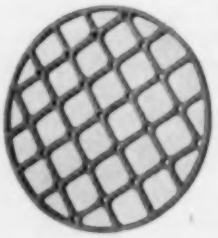
With this instrument, a known sample is placed in series in one of two electrical circuits, and the unknown specimen in the other. When the two pieces of metal are brought into contact, the lighted indicator registers on an easily-read scale whether or not the two are of the same analysis.

Official U. S. Navy Photograph

For the Engines of Our Naval Craft

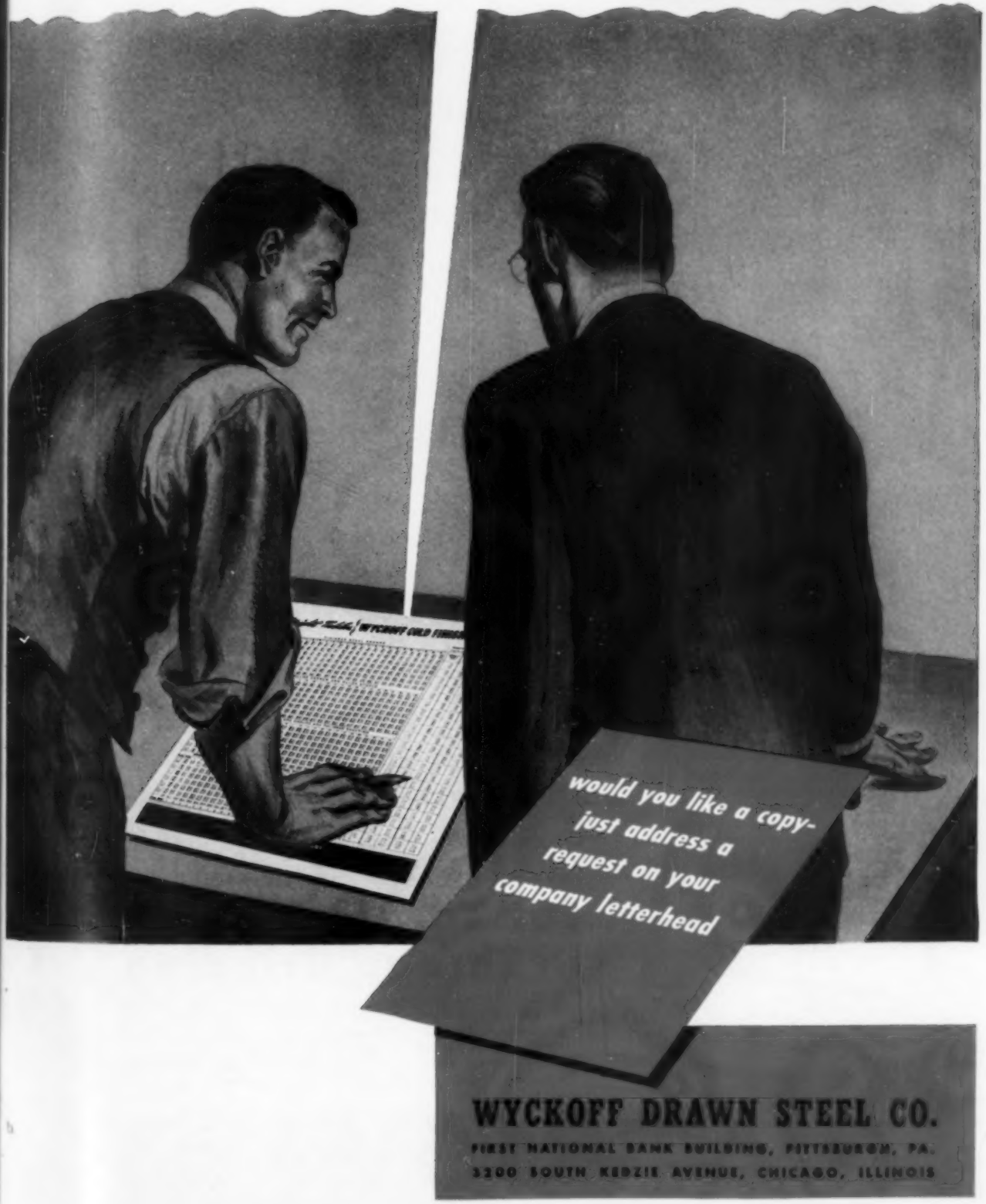
Michiana Trays and Fixtures Used in Heat-Treating Vital Parts

● The speed and power of the U. S. PT Boats give these fighters their advantages on offense and defense . . . Reliability of their engines hinges on the dependable performance of every part, and MICHIANA well recognizes its responsibility in the production of the heat-resistant alloy furnace trays and fixtures used in the heat-treatment of vital parts of the famous Packard motors that power these craft. MICHIANA PRODUCTS CORPORATION, Michigan City, Ind.



MICHIANA
Heat-Resistant and
Corrosion-Resistant
ALLOY CASTINGS

many users of cold finished steels are finding this new Wyckoff weight chart *invaluable*



WYCKOFF DRAWN STEEL CO.

FIRST NATIONAL BANK BUILDING, PITTSBURGH, PA.
3200 SOUTH KEDZIE AVENUE, CHICAGO, ILLINOIS

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New corrosion data work sheet acts as check list to insure consideration and evaluation of all factors influencing corrosive action. International Nickel Co. Bulletin Eg-45.

Enduro stainless steels. Republic Steel Corp. Bulletin Hf-8a.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin Kd-85.

Free Machining Steels. Monarch Steel Co. Bulletin Cd-255.

Tool Steels. Bethlehem Steel Co. Bulletin Ce-76.

Die Steels. Latrobe Electric Steel Co. Bulletin Ld-208.

Enameling iron sheets. Inland Steel Co. Bulletin Ld-295.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin Kd-229.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin Hb-4.

Four Coppco tool steels. Copperweld Steel Co. Bulletin Cf-311.

Stainless steel. Allegheny Ludlum Steel Corp. Bulletin Df-92.

New process embodying both chemical and temperature controls for production of low carbon open hearth case carburizing steel is described in bulletin by W. J. Holliday & Co. Bulletin Bg-293.

Shop notes on the machining of stainless steels. Rustless Iron & Steel Corp. Bulletin Nf-169.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin Eg-106.

Cromoco air-hardening die steel for high production is described in new leaflet by Firth-Sterling Steel Co. Bulletin Gg-177.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin Gg-450.

NON-FERROUS METALS

Reynolds Metals Co. has issued two color charts showing marking for identification of wrought aluminum alloy products, rod, bar, tubing and shapes, and for aluminum alloy sheet. Bulletin Fg-436.

Heat treatment of aluminum bronzes is one of the articles in leaflet issued by H. Kramer & Co. Bulletin Fg-508.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin Af-337.

Die casting equipment. Lester-Phoenix, Inc. Bulletin Kf-437.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin Eg-126.

Bronze. Frontier Bronze Corp. Bulletin Kf-455.

Copper Alloys. American Brass Co. Bulletin Kd-89.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin De-307.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

Brass and bronze castings. Hammond Brass Works. Bulletin Df-371.

Reference on properties of lead. St. Joseph Lead Co. Bulletin If-415.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin Bg-239.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

Dowmetal data book. Dow Chemical Co. Bulletin Ec-215.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin Nf-163.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin Cg-481.

Surface protection for magnesium. American Magnesium Corp. Bulletin Cg-482.

Standard specifications for all grades of aluminum alloys (casting grades only). Federated Metals Div., American Smelting and Refining Co. Bulletin Cg-478.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin Cg-483.

Everyone joining nonferrous metals needs the new 12-page Westinghouse Brazing Booklet, crammed with timely ideas for saving man-hours and critical materials. Westinghouse Elec. & Mfg. Co. Bulletin Dg-134.

"The Story of Magnesium" is name of illustrated booklet issued by the Permanente Metals Corp. Bulletin Gg-523.

WELDING

"Sureweld" protected arc electrodes. Hollup Corp., division of National Cylinder Gas Co. Bulletin Ag-331.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin Ff-393.

Electrode quantity and welding time graph. Arcos Corp. Bulletin Ld-191.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin Co-63.

Sciaky radial portable welder. Sciaky Brothers. Bulletin Kf-425.

Two-stage "Regolator" for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

Speed is increased 20 to 30% and power costs cut one-third with the Flexarc A-C welders described in new booklet by Westinghouse Electric & Mfg. Co. Bulletin Ag-134.

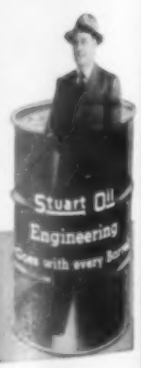
Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin Cg-220.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin Cg-54.

Shield Arc electrodes. McKay Co. Bulletin Gf-248.

Modern goal in equipment design and welding technique is outlined in bulletin "New Advances in Arc Welding Equipment Design" by Harnischfeger Corp. Bulletin Dg-171.

Use Handy Coupon on Page 152 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 152, 156, 158, 160, 162, 164, and 168.

"SUPER-KOOL" "81X"
Thred Kut "99"
Stuart
Grinding Oils
"Excelene"
. . . for Top Efficiency in Thread Grinding
STUART Thread Grinding Oils are in wide use, giving unequalled efficiency at nominal cost. Developed in co-operation with leading manufacturers of thread grinding machines and wheels, they have been proved in many of the largest and most modern metal working plants . . . A Stuart Oil Engineer will gladly help you achieve top efficiency in thread grinding. Ask him to come in.


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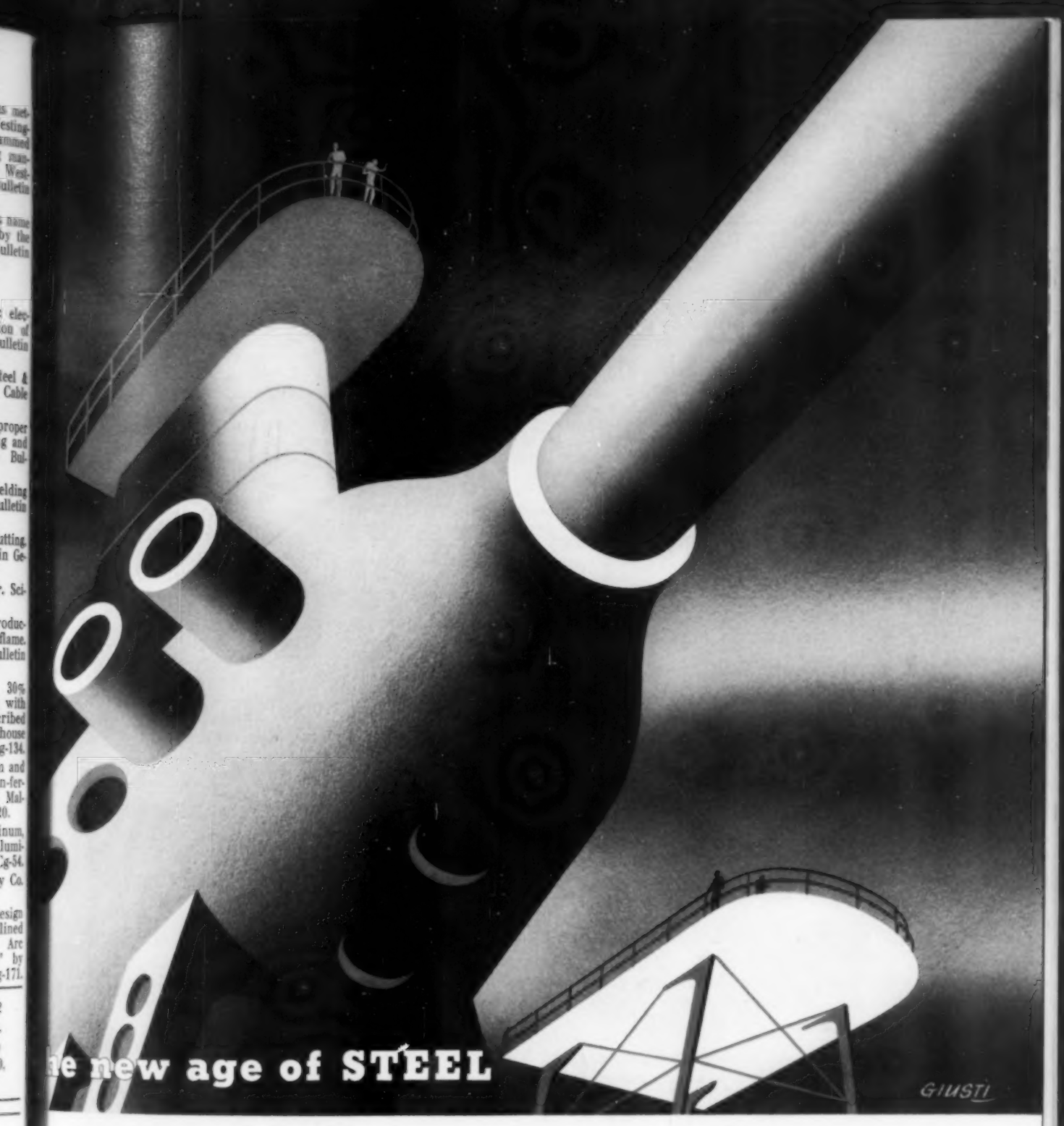
D. A. STUART OIL CO.
Chicago, U.S.A. • LIMITED • Est. 1865
Warehouses in Principal Metal Working Centers



Power of the future. • • • Whether it comes from the harnessing of rivers, from the cracking of atoms or from huge engines burning coal or oil—always there is the problem of application. • • • It is here that the engineer and the creative steel-maker join forces—here that Midvale, specialist in working large masses of steel, will bring skill and knowledge to power transmission of the future.

MIDVALE

Custom Steel-Makers to Industry

PHILADELPHIA • *New York • Chicago • Pittsburgh • Washington • Cleveland • San Francisco*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Precision welder. Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

Improved method for welding cast iron is described by Eutectic Welding Alloys Co. Bulletin Fg-301.

Nu-Braze No. 4, an improved silver brazing alloy for use with ferrous and nonferrous metals is described by Sherman & Co. Bulletin Fg-514.

Direct-current, single-operator arc welders are discussed in new 12-page bulletin issued by General Electric Co. Bulletin Gg-60.

New electrode comparsion chart has been issued by Air Reduction Co. and is said to simplify buying of competitive welding electrodes. Bulletin Gg-69.

New "200" welder is described by Allis-Chalmers in Bulletin Gg-522.

TESTING & CONTROL

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin Eg-67.

Just out is Westinghouse's new book containing a wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin Eg-134.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin Hc-6.

New fixtures and accessories to extend usefulness of X-ray quartz analysis apparatus are described by Philips Metalix Corp. Bulletin Fg-471.

New illustrated booklet describes time-saving metallurgical polishing equipment by Tracy C. Jarrett. Bulletin Fg-303.

New Picker X-Ray accessory and supply catalog illustrates many accessories employed in industrial radiography. Bulletin Eg-348.

Radiographic identification of negatives with lead markers is described in leaflet by H. W. Knight & Son, Inc. Bulletin Eg-503.

Electric heaters and controls for industrial and laboratory. American Instrument Co. Bulletin Eg-259.

12-page catalog describes electric motor valve operators as applied to standard temperature control systems for fuel-fired furnaces. Automatic Temperature Control Co. Bulletin Fg-384.

Carbon-Meter for rapidly determining carbon at the furnace is described in booklet by E. Leitz, Inc. Bulletin Fg-47.

8-page bulletin describes line of new convertible free-vane air-operated controllers. Bristol Co. Bulletin Fg-87.

New 29-page catalog — Microman Electric Control — has just been issued by Leeds & Northrup Co. Bulletin Bg-46.

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin If-401.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin Bf-345.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

Potentiometer temperature indicators. Foxboro Co. Bulletin Ef-21.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin Kf-206.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin Hb-180.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin Df-377.

Use Handy Coupon on Page 152 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 152, 154, 158, 160, 162, 164 and 168.

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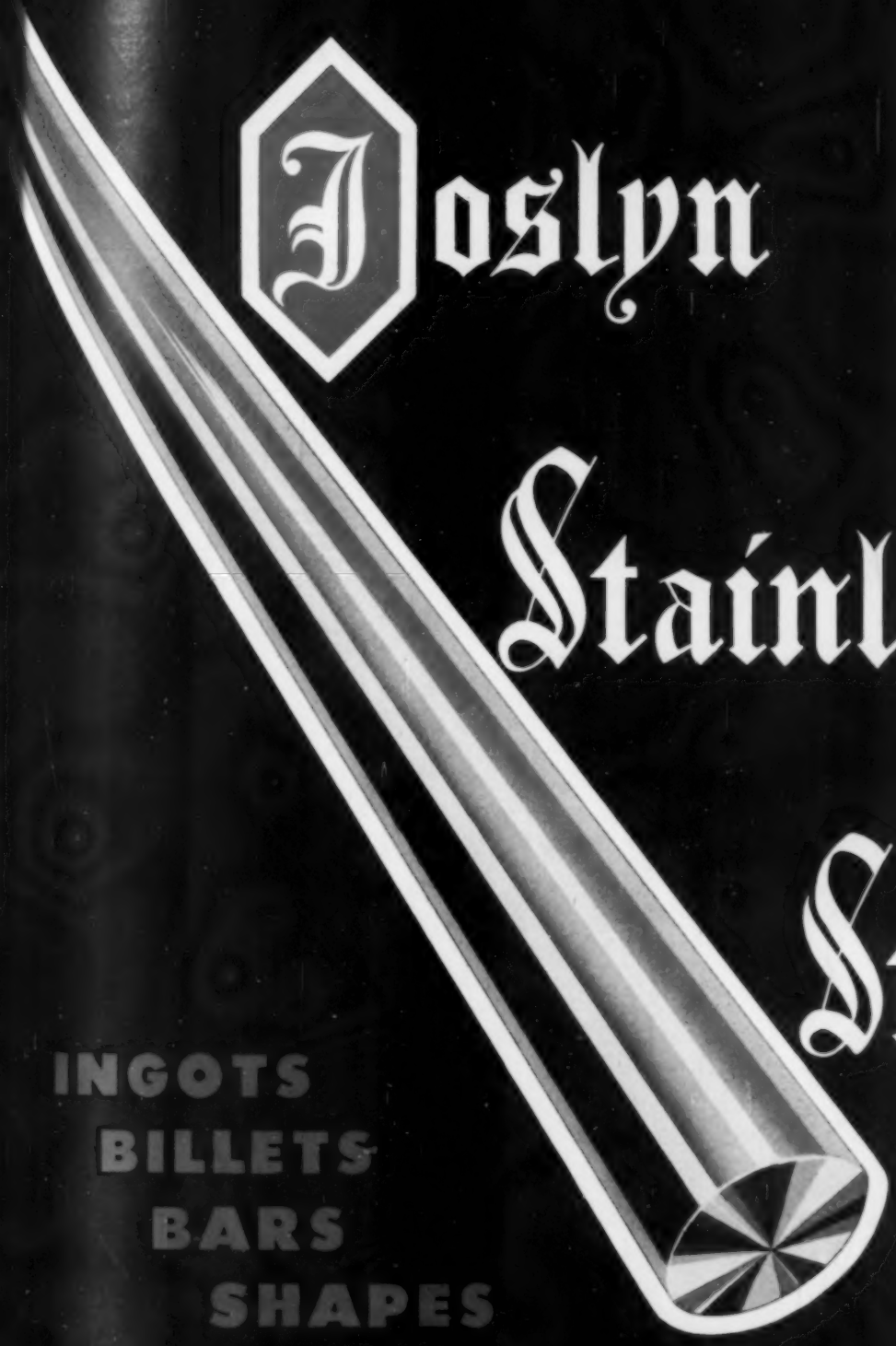

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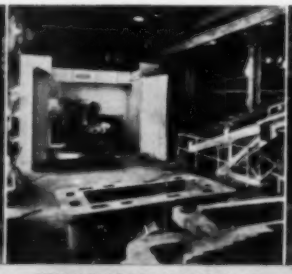

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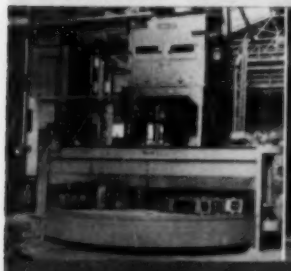

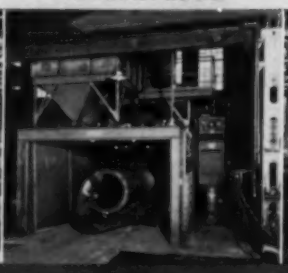

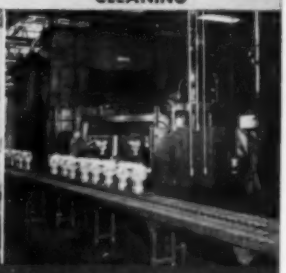

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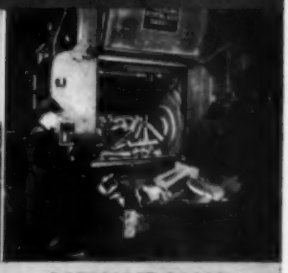

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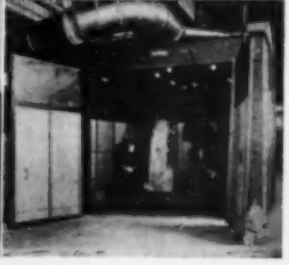

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

Surface Analyzer. Brush Development Company. Bulletin Kd-288.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin Kc-37.

X-Ray metallurgical laboratory service. Claud S. Gordon Co. Bulletin Nf-53.

64-page booklet on the precision control of industrial processes. Brown Instrument Co. Bulletin Nf-3.

Dillon tensile tester and the Dillon dynamometer are described and illustrated in new leaflet issued by W. C. Dillon & Co. Bulletin Ag-466.

An innovation in the manual methods of gas analysis known as Catalysis is described in leaflet by Burrell Technical Supply Co. Bulletin Dg-213.

Catalog and engineering data book on industrial thermocouples. Arklay S. Richards Co. Bulletin Dg-330.

Optical Aids. Bausch & Lomb Optical Co. Bulletin Ce-35.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

Metallographic polishing powder. Conrad Wolff. Bulletin Cf-368.

Metallurgical Equipment. Adolph I. Buehler. Bulletin Ke-135.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

Identometer for rapid identification of steel is described and illustrated in booklet by Dravo Corp. Bulletin Gg-516.

New condensed catalog gives prices and descriptions of instruments offered by Wheelco Instruments Co. Bulletin Gg-110.

Eberbach micro hardness tester is illustrated and described in new booklet by Eberbach & Son Co. Bulletin Gg-524.

HEATING • HEAT TREATMENT

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin Eg-399.

Homo method for nitriding is described and illustrated in new 19-page catalog by Leeds & Northrup. Bulletin Eg-46.

Use Handy Coupon on Page 152 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 152, 154, 156, 160, 162, 164, and 168.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin Ef-386.

Induction heating. Induction Heating Corp. Bulletin Ef-323.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin Ag-310.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin He-41.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

Hagan rotary forging furnaces are described in bulletin by George J. Hagan Co. Bulletin Cg-476.

Comprehensive, 100-page textbook describes constructional features, capacities, operation and instrumentation of nitriding furnaces. Nitralloy Corp. Bulletin Fg-116.

New 20-page booklet describes centrifugal blowers and exhausters. Roots Connersville Blower Corp. Bulletin Fg-131.

Profusely illustrated booklet shows many applications of Lindberg furnaces for accurate heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin Fg-66.

Heavy duty high temperature alloy steel fans are described by Despatch Oven Co. Bulletin Fg-123.

48 illustrated pages describe Precision - Freas constant temperature control cabinets. Precision Scientific Co. Bulletin Fg-510.

"The Trend Is Toward Salt" is title of interesting leaflet showing several examples of heat treatment. Ajax Electric Co. Bulletin Fg-43.

Unusual accessibility and other features of new high temperature fans are described in new leaflet by Mahr Mfg. Bulletin Fg-5.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin Lf-203.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin Ce-302.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin Eg-445.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin Lf-461.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

Faster production with Tocco hardening, brazing, annealing and heating machines. 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

Kleen-well oil strainers for quench oil cooling systems. Bell & Gossett Co. Bulletin Lf-287.

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Other Manufacturers' Literature Listed on Pages 152, 154, 156, 158, 162, 164 and 168.

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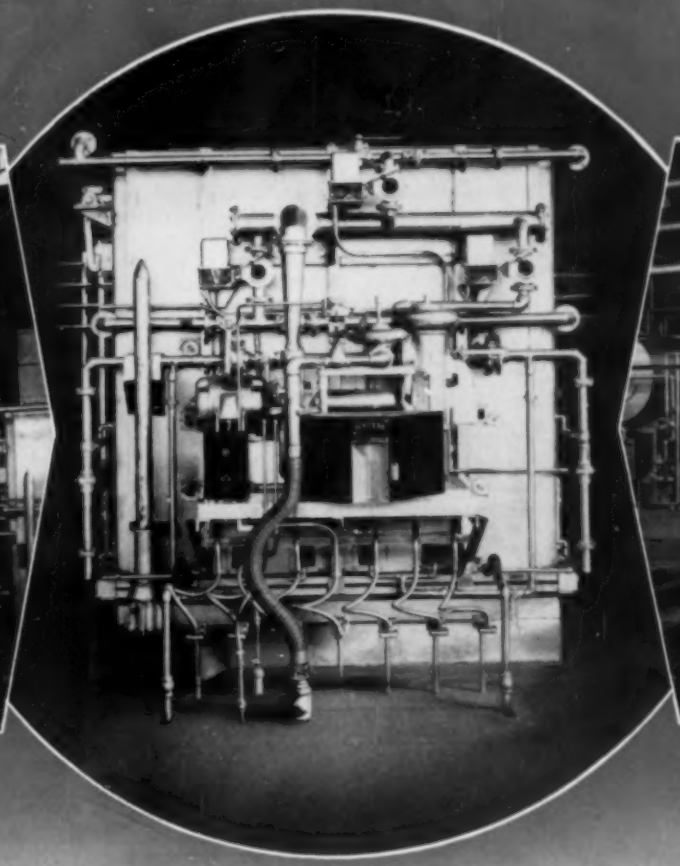
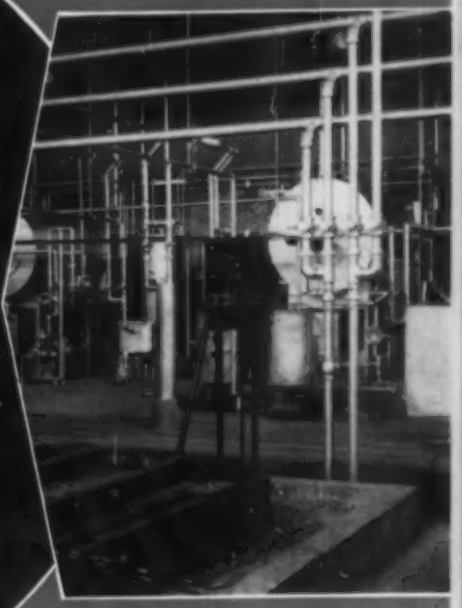
Here the heating hood is raised, showing the inner cover under which the charge is placed. After the heating-soaking cycle is completed, the hood may be removed and placed on another charge, leaving the inner cover in position until the charge has finished cooling.



This shows the heating hood in place with thermocouples and fuel connections ready for operation. Notice the careful, clean-cut engineering construction.



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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Gas cracking unit for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels. Hevi-Duty Electric Co. in new Bulletin Lf-44.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel. United Chromium, Inc. Bulletin Lf-463.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin Lf-443.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin Ff-286.

Heat treating furnaces. Johnston Mfg. Co. Bulletin Ff-155.

Drycolene. General Electric furnace atmosphere. Bulletin Df-60.

Dual-Action quenching oil. Gulf Oil Co. Bulletin Df-360.

Electric box type and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

Industrial Furnaces. W. S. Rockwell Co. Bulletin Kc-34.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin Nc-15.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners is described in new bulletin by the North American Mfg. Co. Bulletin Dg-138.

Blue Print for Industry is title of new handbook presenting oven engineering information on 28 installations with description of design and process. Industrial Oven Engineering Co. Bulletin Dg-494.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin Cg-484.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin Cg-226.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin Cg-11.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

Heat treating furnaces. McCann Furnace Co. Bulletin Kf-446.

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

Furnaces. Tate-Jones Co. Bulletin Kf-447.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin Ce-219.

New Van Norman induction heating units are comprehensively described and typical operations pictured in attractive 8-page folder by Van Norman Machine Tool Co. Bulletin Dg-487.

New 8-page, well-illustrated catalog describes equipment for flame-hardening, flame-annealing, mechanized-brazing, preheating and other localized open heat treatments by the Selas Co. Bulletin Dg-214.

High and low temperature direct fired furnaces as well as convection types for stress relieving and drawing are described in new 8-page leaflet by R-S Products Corp. Bulletin Dg-234.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequecy Laboratories, Inc. Bulletin Kc-211.

Vertical Furnace. Sentry Co. Bulletin Ne-114.

Conveyor Furnaces. Electric Furnace Co. Bulletin Be-30.

New Electric Furnace. American Electric Furnace Co. Bulletin Gd-2.

Newly developed salt bath material for use in Martempering process. E. F. Houghton & Co. Bulletin Dg-38.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin Cf-24.

Furnace Experience. Flinn & Dreifein Co. Bulletin Bc-82.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin Nf-305.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin Bb-187.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin Nf-141.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin Ke-260.

High Temperature Fans. Michiana Products Corp. Bulletin Hb-81.

Turbo-compressors. Spencer Turbine Co. Bulletin Cf-70.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin Ag-448.

Various Surface Combustion installations engineered for batch carburizing on a production basis are shown in new leaflet. Bulletin Gg-51.

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Other Manufacturers' Literature Listed on Pages 152, 154, 156, 158, 160, 164 and 168.

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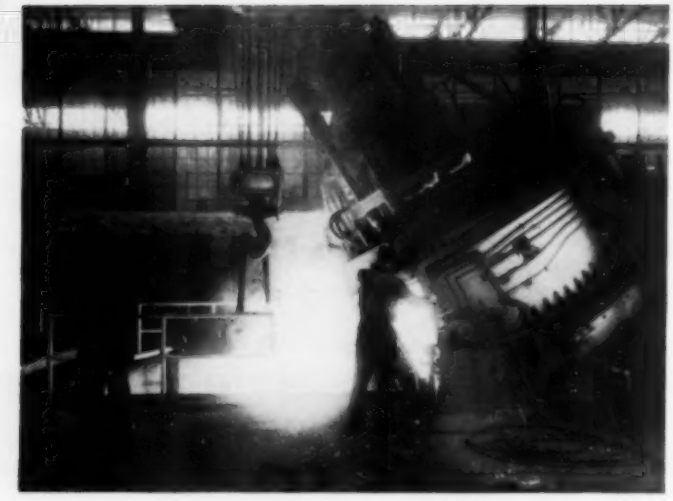

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin Ce-75.

Cromox, a new protective refractory coating material for prolonging the life of firebrick, insulating firebrick, and castable refractories in coal, oil, gas-fired and electric furnaces, as well as in nonferrous melting furnaces. Federal Refractories Corp. Bulletin Eg-497.

Heavy Duty Refractories. Norton Co. Bulletin Ie-88.

Super Refractories catalog. Carborundum Co. Bulletin Ld-57.

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin Ef-218.

Conductivity and heat transfer charts. Johns-Manville. Bulletin Df-100.

Ramix bottom for basic open hearth furnaces. Basic Refractories, Inc. Bulletin Nf-192.

Brickseal refractory coating. Brickseal Refractory Co. Bulletin Ag-469.

FINISHING, PLATING, CLEANING

Fine illustrated folder describes Roto-Finish equipment and its use for de-burring, buffing, polishing and coloring. Sturgis Products Co. Bulletin Eg-504.

A protective, deep black finish to steel. Heatbath Corp. Bulletin Hf-189.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin Ne-329.

Four new booklets describe blackening processes for metals, for aluminum, zinc and copper. Enthone Co. Bulletin Fg-240.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin Bf-352.

Pickling. Wm. M. Parkin Co. Bulletin Ff-193.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment. Detroit Rex Products Co. Bulletin Lf-111.

Airless Rotoblast. Pangborn Corp. Bulletin Hf-68.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin Hd-29.

Degreasers. Phillips Manufacturing Co. Bulletin Nc-254.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin Kf-456.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin Kf-426.

New industrial washing equipment is described by American Foundry Equipment Co. Bulletin Dg-112.

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Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin Kf-451.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin Hd-271.

Alloy additions to gray iron, malleable and semi-steel are discussed and newest information presented in booklet by Niagara Falls Smelting & Refining Corp. Bulletin Dg-467.

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Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin Fg-511.

Meehanite Castings. Meehanite Research Institute. Bulletin Bf-165.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin Ld-32.

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Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin Ag-144.

48-page catalog on manganese steel. American Manganese Steel Div., American Brake Shoe & Foundry Co. Bulletin Cg-9.

Alloy Castings. Ohio Steel Foundry Co. Bulletin Dg-40.

Spring Design and Engineering is title of new manual issued by Mid-West Spring Mfg. Co. Bulletin Gg-514.

Manual on welded steel tubing for heat exchanger and condenser use has been issued by Formed Steel Tube Institute. Bulletin Gg-518.

New process of tube spinning developed by Wolverine Tube Div., Calumet & Hecla Consolidated Copper Co., is described in brochure just released. Bulletin Gg-519.

Use Handy Coupon on Page 152 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 152, 154, 156, 158, 160, 162 and 164.

The author gave an elementary introduction to the important alloy known as cartridge brass in the June issue of Metal Progress, and in this second article shows how the tensile properties of annealed 70-30 brass react to cold work and how annealing modifies the properties of cold worked material. Much modern processing depends on proper grain size control, and the author shows how the brass mill achieves this, and discusses the necessary degree of control.

CARTRIDGE BRASS

(cold working and annealing)

By L. E. GIBBS

Technical Advisor, Rome N. Y. Division, Revere Copper and Brass, Inc.

IN the previous article in the June issue of *Metal Progress* ("Cartridge Brass — an Elementary Introduction") it was briefly pointed out that

1. Brasses are not susceptible to heat treatment for hardening but that cold working is the only means of increasing strength and hardness.

2. Annealing following cold working restores ductility, the extent of the annealing controlling the degree of ductility (grain size being the preferred means of measurement).

3. Cold working and annealing go hand in hand and one cannot be changed indiscriminately without affecting the other.

In a brass mill, cold working and annealing relationships are established through long practice for the various products (sheet, strip, rods, tubes and shapes) and thus the properties are controlled in the "break-down" and "run-down" stages, as well as in the finishing operations — "break-down" and "run-down" being the primary and intermediate steps required to reduce a raw cake into sheet and strip, or a billet into rod, tube, or shapes, nearly to the physical dimensions desired by a customer. For sheet and strip these operations consist of either hot rolling or cold rolling for breaking down, depending upon mill equipment, and hot rolling or hot extrusion to other forms. Running down is usually a cold working operation for all forms of brass.

For the cold working operations, the three basic principles stated above are applied; that is, cold reductions as well as annealing in intermediate steps are standardized, a rough rule for sheet and strip being 50% reduction, followed by an anneal for an approximate 0.050-mm. grain size minimum. Actual reductions on rod, tubes and shapes are not so simply arranged, because mill equipment may not be available, and because of limitations on size and shape. Obviously, it is well to avoid cold working the alloy near its limit (the maximum possible before ductility becomes so low that fracture occurs). Subsequent annealing is primarily designed for economical time and temperature cycles. Desirable grain size averages 0.035 to 0.050 mm. for 70-30 brass; higher copper alloys will anneal smaller in grain size, as shown in Fig. 3 of the article in June.

The finishing operations not only must produce dimensions and accurate shapes ordered by customers within the required tolerances, but also the physical properties best fitting the application to which metal is being applied. This may be determined by specifications of government agencies, national societies, the customer, by experience of the mill with the customer's requirements, or on recommendation by a technical advisor (or similar engineering sales organization) according to operations or application. In any event, mill operations must be arranged to end up with the properties to do the job at hand. Considering some of the variables involved in the control of properties, this is not always as simple as it sounds.

Cold working increases tensile strength,

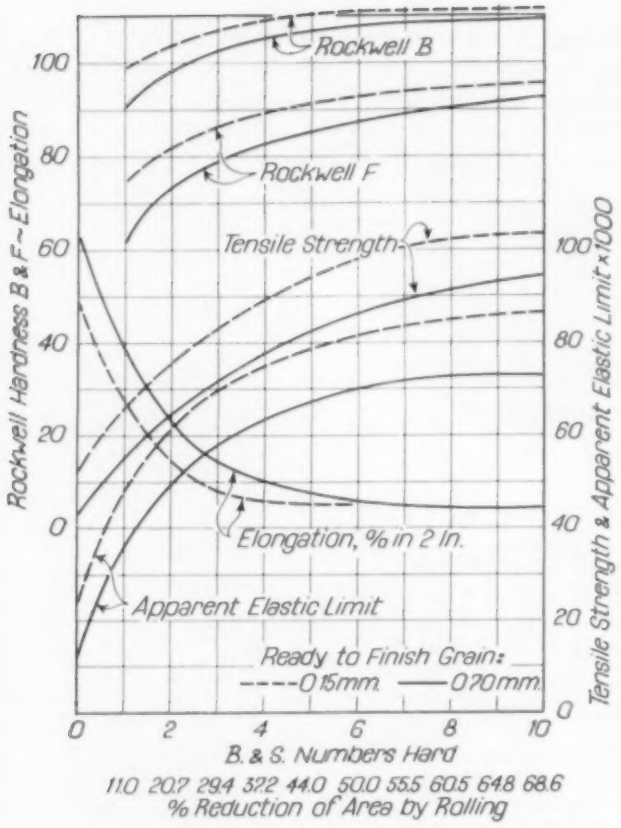

Rockwell B
Rockwell F
Tensile Strength
Elongation, % in 2 In.
Apparent Elastic Limit
Ready to Finish Grain:
---0.015 mm. —0.070 mm.
Rockwell Hardness B & F ~ Elongation
Tensile Strength & Apparent Elastic Limit x 1000
B. & S. Numbers Hard
11.0 20.7 29.4 32.2 44.0 50.0 55.5 60.5 64.8 68.6
% Reduction of Area by Rolling

Fig. 6 — Effect of Ready-to-Finish Grain Size (0.015 and 0.070 Mm.) on the Tensile Properties and Hardness of Cartridge Brass Strip After Definite Reductions by Cold Rolling

apparent elastic limit and hardness, and decreases elongation and reduction of area — no matter if this cold working is by reduction through rolls for sheet or strip; through a die or rolls for rods, bars and shapes; or a die with inside mandrel or "plug" for tubes; or in subsequent fabrication in stamping and drawing, using dies and mandrels (punches). In all these operations the principles are the same.

Discussion following is intended to show the importance of these principles and how they may be applied. To aid us we will consider several charts of physical properties. Figure 6 applies to cold worked sheet and strip in relation to "ready-to-finish" grain size. Figure 7 applies to annealed sheet and strip after cold working. Figures 8 and 9 are for rod. Discussion of Fig. 8 and 9 applies to the ready-to-finish grain size of 0.045 mm., indicating average conditions. The elongation in 2 in., determined in the tensile test on rod, is more indicative of the actual ductility of 70-30 brass than values for strip.

The physical properties of a finished part or form made of brass depend on the last operation. The amount of cold working in that operation necessarily must be enough to meet the specification. Figures 6 and 8 indicate how much this reduction needs to be. If a tubular shape is involved, the cold working must be applied to the inside as well as the outside in the majority of operations, because of surface, dimension and tolerance; "reduction" is therefore based on area as well as wall thickness. Simultaneously, the anneal prior to this final operation has an effect, as Fig. 6 indicates. Characteristically, a large ready-to-finish grain size lowers strength, as compared to a small ready-to-finish grain.

Differences exist also for hardness and elongation, but lack of sensitivity of test methods obscures these differences. In this connection the Rockwell F scale

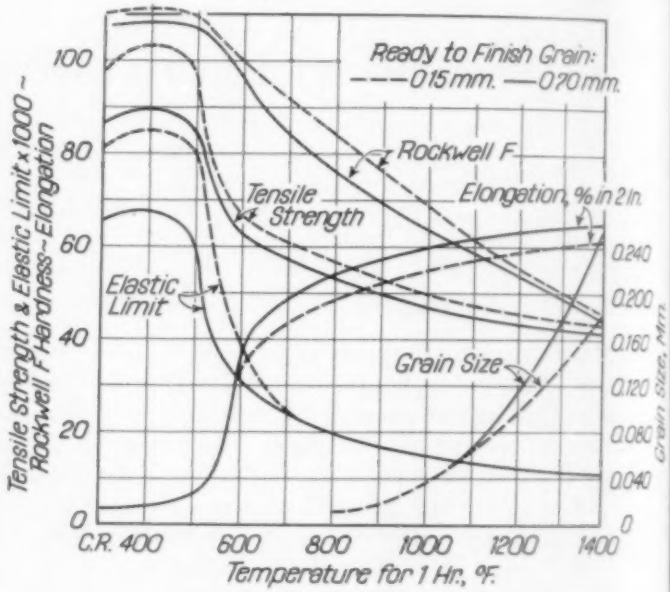

Ready to Finish Grain:
---0.015 mm. —0.070 mm.
Rockwell F
Tensile Strength
Elongation, % in 2 In.
Elastic Limit
Grain Size
Tensile Strength & Elastic Limit x 1000 ~ Rockwell F Hardness ~ Elongation
Grain Size, Mm.
C.R. 400
Temperature for 1 Hr., °F.

Fig. 7 — Effect of Ready-to-Finish Grain Size (0.015 and 0.070 Mm.) on the Tensile Properties and Hardness, as Well as the Final Grain Size, of Cartridge Brass Strip Cold Rolled 6 B.&S. Numbers Hard and Then Annealed 1 Hr. at Temperatures Indicated

over 100 is not reliable. Rockwell B hardness should not be used when greatest accuracy is required on brasses over 6 numbers hard, because differences between small amounts of cold working are not easily detected; tensile strength is a better criterion.

The variations in cold worked properties shown in Fig. 6 and 8 are important when, as an example, a specification requires a range, maximum to minimum tensile strength, of 10,000 psi. Brass mills, on a fairly wide range of products, consistently work to such a tolerance. Any parts maker, working similarly, will necessarily be required to control ready-to-finish grain size: whether it is large or small depends on the results needed and the operations being performed, as will be brought out in a later discussion. The important thing for the present is this rule:

Once ready-to-finish grain size is established, hold it from lot to lot. Otherwise, results will vary — as Fig. 6 shows. How closely grain size must be held will depend upon individual needs; Fig. 6 again is illustrative.

For typical physical properties for various cold rolled tempers, the range between 0.015 and 0.070 mm. ready-to-finish grain size for a given temper would provide a reasonable guide.

Usually, operations prior to ready-to-finish do not affect the final one (see Fig. 7) since the effects tend to "wash out". An exception is most commonly found in the rolling of copper or brass strip in which directional properties are produced and retained in spite of annealing. Evidence of this is usually found, in subsequent cupping operations, by the presence of "ears" about the periphery. Height of these "ears" or high spots on the upstanding edges varies with the degree of directional properties. Their location is usually parallel to and at 90° from the rolling direction for copper (which has four ears, characteristically) and 45° to the rolling direction with four ears for brass, although six will appear when the zinc range enters that of drawing brass. The causes vary, but most severe earing can result from a series of low temperature anneals, producing small grain size, followed by cold working of 4 to 6 B.&S. numbers. For excellent detailed data on this subject refer to "Directional Properties of 68-32 Brass Strip" by H. L. Burghoff and E. C. Bohlen, as well as "Effect of Some Mill Variables on the Earing of Brass in Deep Drawing" by Earl W. Palmer and Cyril Stanley Smith. Both appear in the *Transactions* of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, Vol. 147, 1942.

Cold work leaves its impress on the appearance of a microsection, best shown by fairly light work on coarse grain sizes (Fig. 10). Original grains are almost indistinguishable if ready-to-finish grain size is small, and final working is severe. In an article like a cartridge case head (Fig. 13) many degrees of cold work occur in a relatively short distance, and if such a piece is annealed, a wide variety of grain sizes would result.

Annealing, as is shown in Fig. 7 and 9, decreases tensile strength, apparent elastic limit, hardness, and increases elongation and reduction of area. At the same time, the distorted, stressed crystals typical of cold worked metal are replaced by characteristic equi-axed crystals shown in Fig. 1 and 2 (June *Metal Progress*). The slight increase in

Fig. 8 — Cartridge Brass Rods (Nominally 70% Copper, 30% Zinc) in Diameters up to 1 In. and 0.045 Mm. Ready-to-Finish Grain Size, Were Cold Drawn Various Amounts and Then Tested for Tensile Properties and Hardness

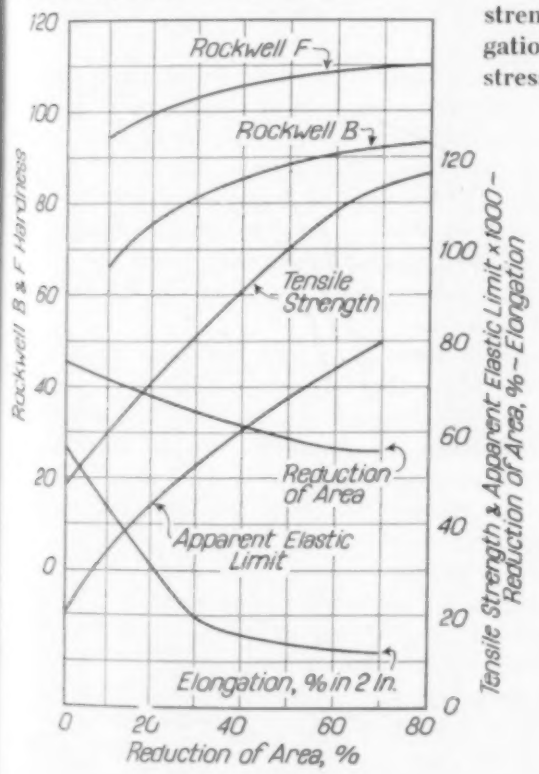
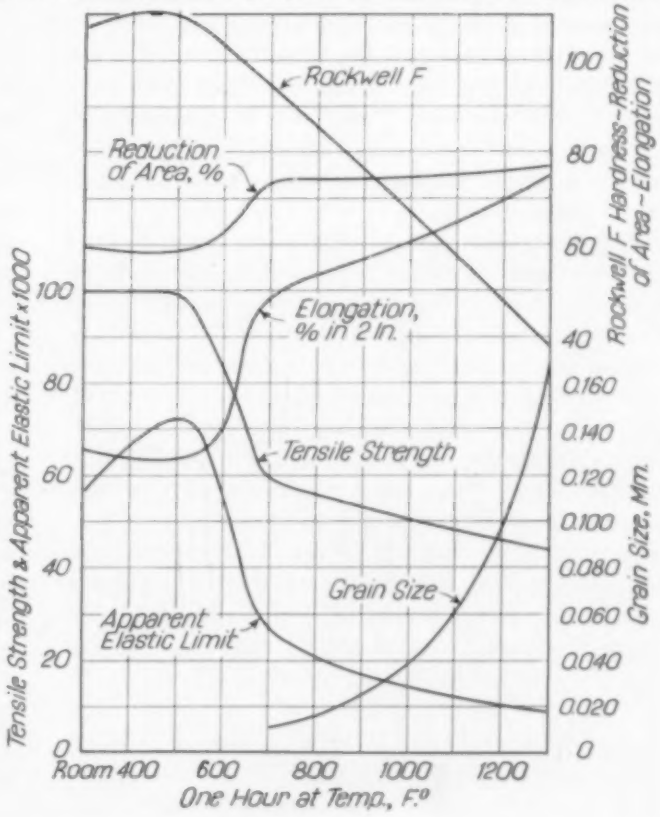


Fig. 9 — Cartridge Brass Rod of Fig. 8, Cold Reduced 50%, Was Annealed 1 Hr. at Various Temperatures. Curves show resulting tensile properties, hardness, and grain size



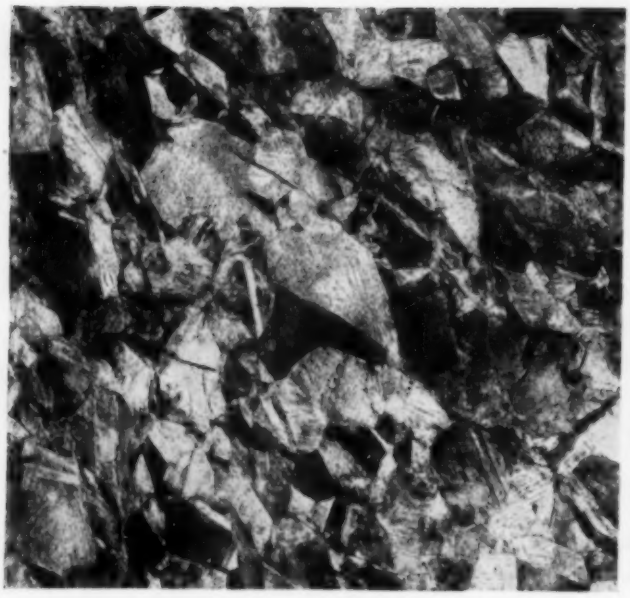


Fig. 10 — Coarse Grained Cartridge Brass After Relatively Slight Cold Working. Original grains are clearly distinguished, although numerous strain lines appear in all of them

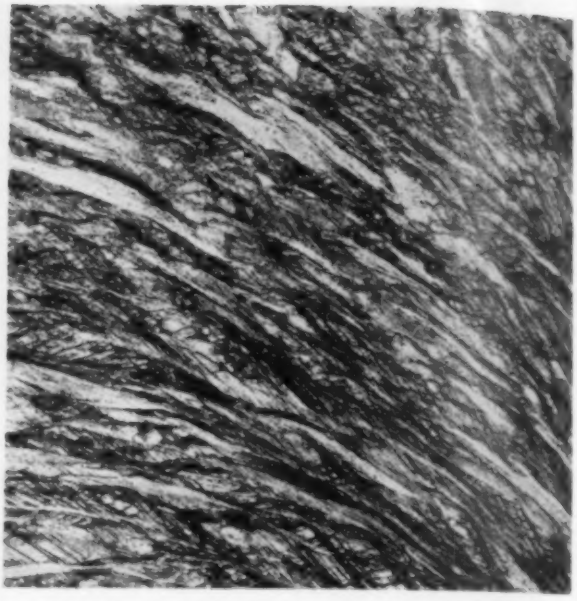


Fig. 11 — Same Brass as Fig. 10 After Much More Severe Cold Work. Crystals have become elongated and boundaries are impossible to distinguish. Structure might be called "fibrous"

strength and hardness after annealing at 400° F. is typical of low temperature annealing. Annealing may be used to restore ductility for further cold working or to remove internal stresses due to cold working (the latter is known as "relief annealing"), or to impart a specific physical property required by a particular use. The extent of the anneal is most dependent on the severity of the cold working which is to follow. (Relief annealing in the true sense does not soften or recrystallize the metal, and will be discussed as a separate subject.) As Table II in the prior article denotes, varying uses determine the optimum grain size.

Results obtained by annealing depend upon several factors, which will now be enumerated and discussed. These principles are applicable to copper and all non-age-hardening copper base alloys, the degree and absolute values of properties varying with circumstances.

1. As prior cold working increases in severity, the lower is the softening and recrystallization temperature. The speed of grain growth and recrystallization also tends to increase.

It is preferred to define "recrystallization temperature" as that temperature that produces a grain size of 0.010 mm. or less (Fig. 12). There are other definitions of more exactness, but the one given is practical enough for our use.

In Fig. 7 and 9 it should be noted that the prior cold reduction is stated as 6 B.&S. numbers and 50% respectively. Consequently, these or other similar annealing curves show only those conditions of softening and grain growth following the given amount of cold work. If prior cold work is less, the curves tend to shift to the right; when very little, such as less than 10% cold reduction, they tend to become much flatter; the characteristic sharp drop in tensile strength, as an example, almost disappears, since the tensile strength before annealing is nearly the same as afterwards.

At the same time, with the *lesser* amounts of cold working other effects are noticed:

(a) Upon annealing, the ready-to-finish grain size tends to be obtained. As an example, if 0.035-mm. grain size metal is worked 5%, a grain size *less* than 0.035 mm. will not result from ordinary annealing, but rather, 0.035 mm. or larger depending upon time and temperature. (It might be mentioned appropriately here that re-annealing of annealed metal is an uncertain process. The original speed of recrystallization and grain growth is lost and tends to be quite sluggish. In brass mill practice, therefore, if grain size was too small on the regular anneal and re-annealing was necessary to increase it to some required value, more frequently than not it would be necessary to try several times. Especially would this be true if an increase of 0.010 from, let us say, 0.030 to 0.040 mm. average is wanted. Obviously, if the grain size was too high, re-annealing would not reduce it, and unless further cold working can be applied, the metal must be used elsewhere or scrapped.)

(b) Light cold working may increase hard-

Table III — **Hardness Versus Grain Size for Cartridge Brass**

Grain Size	Hardness	
	Rockwell F	Rockwell 30T
0.015 mm.	72 to 85	33 to 50
0.025	67 to 79	27 to 42
0.035	65 to 76	25 to 38
0.050	61 to 73	20 to 35
0.070	54 to 67	
0.120	50 to 62	

ness (particularly since the determination of hardness of thin sections is largely a surface test), yet metallographic examination may show slight evidence of cold work or none, either by strain lines or by deformation. This is typical of several mill operations, such as light passes on strip for stiffening the piece to give it better blanking properties, or "sinking" in tube making, which is drawing through a slightly smaller die without using an interior plug or mandrel.

2. Grain size increases as temperature increases.

Curves in Fig. 7 and 9 show the grain sizes which include the minimum and maximum range likely to be encountered in commercial operations of all types. As previously mentioned, light gage strip for small articles usually performs best when it has grain size of 0.050 mm. or under. Heavy gages, usually because of severity of operations, are over this — typical being an Army Specification 57-173B for cartridge brass disks requiring gages up to and including 0.400 in. to have grain size of 0.055 to 0.115 mm., and thicker gages to have grain size of 0.075 to 0.150 mm.

(Grain sizes over 0.200 mm. are rarely produced in ordinary work.)

Accordingly, deep drawing ability corresponds roughly to the grain size. The larger the grain size the deeper the draw obtainable. Some exceptions and qualifications to this statement will be given later.

Referring specifically to Fig. 7 and 9, it will be noted that considerable softening occurs before the recrystallization temperature is reached, somewhere around 750° F. These curves are typical of alloys annealed after a considerable amount of cold work. With electrolytic copper the drop is very sudden, unalloyed copper being much more sensitive in this respect than the brasses are. Hence, in estimating the previous treatment of an "unknown" sample of 70-30 brass, low hardness and strength with distorted, work hardened crystals most likely would indicate an anneal within the range between softening and start of grain growth.

In commercial practice, however, it is difficult to obtain physical properties by annealing between the range of "cold worked" and "softened", for metal is usually annealed and then cold worked to the required degree. As an example, in Fig. 6 a tensile strength between 65,000 and 90,000 psi. calls for 1½ to 7 B.&S. numbers reduction. In Fig. 7 the same tensile strength range is covered by anneals between 500 and 600° F., but the speed of softening is so great that it is nearly impossible to "catch the required property on the down slope of the curve" with ordinary equipment. It is done under certain definite conditions and with alloys other than 70-30 brass, but not 100% successfully, some metal becoming too soft. Therefore it is not practical to soften metal partially

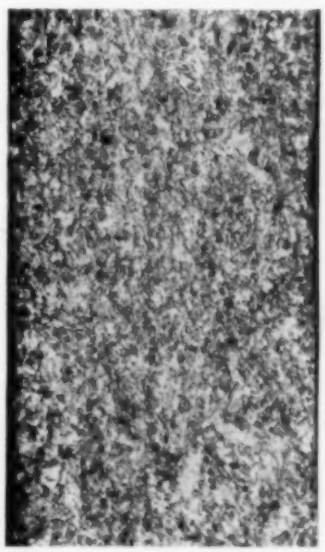
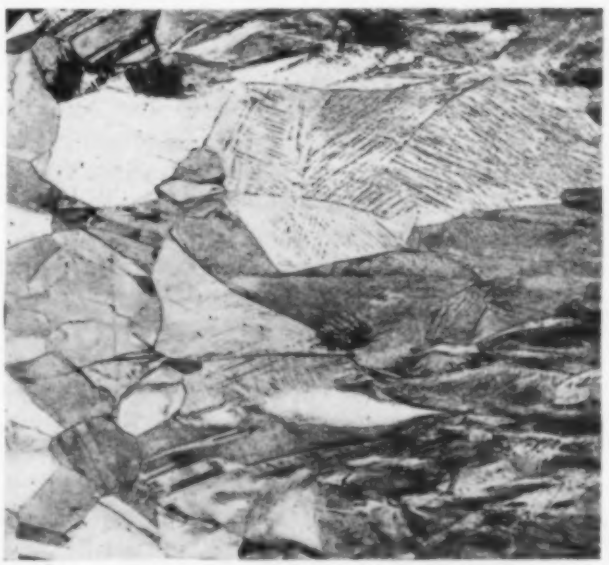


Fig. 12 (Left) — Recrystallized Brass (Fine Grained, Less Than 0.010 Mm.). Illustration is from the heavily-worked wall of a small-caliber cartridge

Fig. 13 (Below) — Rapid Transition From Light to Heavy Cold Work Near Indent in Cartridge Case Head, Originally of Large Grain Size (About 0.200 Mm.). Grain size control of such articles is next to impossible, as the cold worked material would recrystallize to a small grain size under certain conditions, whereas the large, unstrained crystals would remain the same size as they are



by annealing after it has been made too hard.

For physical properties commercially expected with varying grain size, a good standard is given in American Society for Testing Materials' Specification B36-42T for Alloy No. 6, as shown in Table III, page 247.

In variations incident to commercial operations, overlapping of tensile strength, apparent elastic limit and other properties is to be expected, hence: Use grain size for best control.

3. With a given amount of cold work, grain size after annealing will vary according to type of furnace equipment.

It goes without saying that annealing curves shown here are only guides for actual annealing practice. Every furnace must be calibrated individually, especially as to

(a) Source of heat.

(b) "Temperature head"—excess temperature of gases, atmosphere or other heating medium over that temperature required to produce a given grain size.

(c) Cross section of parts or pieces of charge.

(d) Weight of charge.

(e) Time.

(f) Grain size tolerance required.

In the last analysis the amount of grain size control needed will determine the type of furnace equipment. ("This does not constitute an endorsement . . . . . !") Modern requirements of deep drawing have made it necessary for the brass mill to control grain sizes closely — for instance, for average grain size between 0.010 and 0.050 mm., a tolerance of ±0.005 mm. from that specified. This requires furnaces capable of evenly distributing the heat throughout the charge and at such a rate that no part gets hotter, or stays hot longer, than another. Such equipment may be of two types — "batch" and "continuous". In the former a typical design burns fuel in an outside chamber, the products of combustion being blown about and through the charge. In this case control is such that a mean temperature head of 25° F. is achieved. Consequently, no part of the charge gets hotter than it should, regardless of cross-section, weight, or placement. Time in the furnace is several hours.

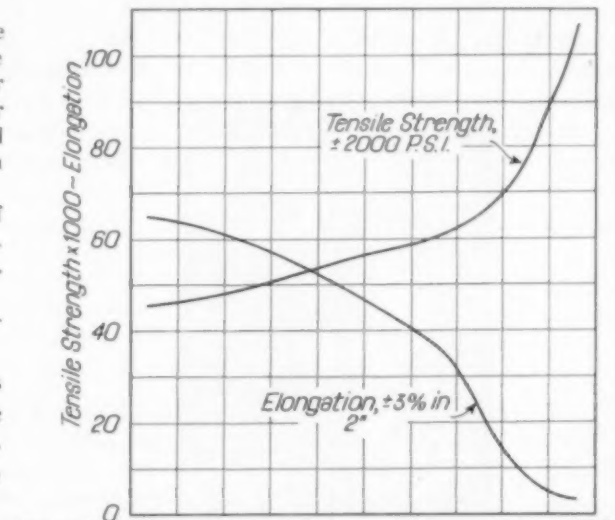


Fig. 14 — Conversion Chart for 70-30 Brass Strip, Tested for Hardness by Four Rockwell Scales Using ⅛ In. Ball. Scale B imposes a 100-kg. load, F a 60-kg. load, 15-T a 15-kg. load, and 30-T a 30-kg. load

The continuous type of furnace, on the other hand, carries a temperature head of 150 to 200° F. over that needed, and the metal travels through the heat zone continuously. Provision is made here also for circulation of atmosphere, although in a different manner. Time in furnace may be 15 to 45 min. This type of furnace is particularly adapted to tube annealing, while the batch type is adapted to coiled strip and other relatively dense and compact metal masses.

The types of furnaces just described illustrate the principles used for close grain size control. If such control is not needed, or this type of equipment is not available, then certain factors must be considered in more detail for calibrating the furnace. Unless heat is evenly circulated to all parts of the charge, the type of heat should be considered. If it produces hot spots, due placement of the heavier sections of metal nearer to it tends to smooth out the heating rate.* If the entire atmosphere is several hundred degrees higher than needed — that is, the furnace runs on a high temperature head — the metal cross section should be similar for all pieces in the charge to avoid uneven heating; in other words, keep all parts of the charge from becoming hotter than desired, or one portion exposed for a longer time than another. If this is not done, grain size will be larger than expected, since increasing time at temperature increases grain growth. Naturally, pyrometers should be used to detect temperature differentials.

Annealing time will be affected by the weight of metal charged, as all know. However, the effective annealing time for brasses is only that at which grain growth proceeds, within commercial limits. Practically speaking, in the batch type furnace an average time of 40 min. for metal at temperature is enough, although heating time may be several hours. This gives sufficient time for complete recrystallization and grain growth to occur, yet not *(Continued on page 292)*

*This assumes that the section is not subject to cracking by differential expansion.

WELDING CONTRACTION,

AND "LOCKED-UP" STRESSES

From a Bulletin Issued by the British Admiralty

A GREAT deal has been written on welding contractions and "locked-up" stresses, but considerable misunderstanding still exists on this subject even among those who have long experience with welding. Possibly this is due in part to the tendency of some to enter into too many technicalities and complications. It is essential to welding progress that it should be generally recognized that locked-up stresses cannot be disregarded, but they can be avoided provided certain fundamental principles are fully understood and techniques are modified accordingly

When a bar of iron is heated, as shown in Fig. 1—that is, with freedom in all directions—it returns to its original length and diameter on cooling, and there is no contraction in length or residual (locked-up) stress. When, however, a bar is heated, as in Fig. 2, with ends restrained against expansion by heat, all the excess volume of metal must go laterally, to increase the diameter of the bulge. On cooling, this excess metal cannot return to its proper place, it remains in its upset position, and the bar contracts in length, leaving a permanent bulge at the heated spot, and the cool bar is shorter than the original length (Fig. 3). In other words, the center part of the bar has been upset by the compressive forces indicated in Fig. 2 while the center was plastic.

In the foregoing cases there has been no residual stress, but imagine that the ends of the bar had been restrained so that the bar could not contract; then there would have been a residual stress (tension) in

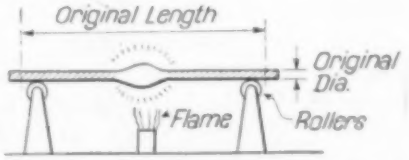


Fig. 1 — No restraint. Hot region expands freely and contracts freely. No contraction or residual stress.

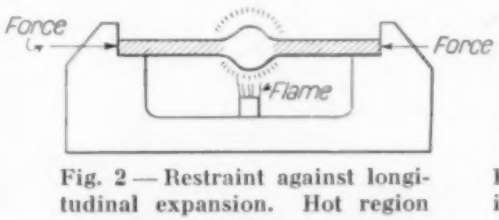


Fig. 2 — Restraint against longitudinal expansion. Hot region expands and diameter upsets.

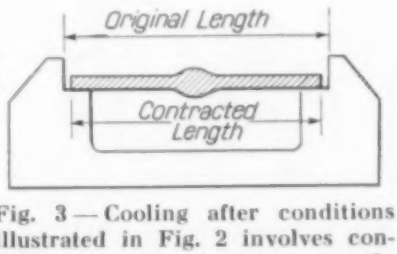


Fig. 3 — Cooling after conditions illustrated in Fig. 2 involves contraction, and bar shortens in length. Contraction but no residual stress.

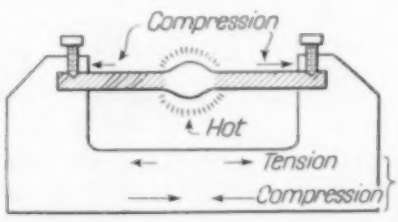


Fig. 4 — Same condition as Fig. 2 during heating. Note bending stresses induced in base of clamp.

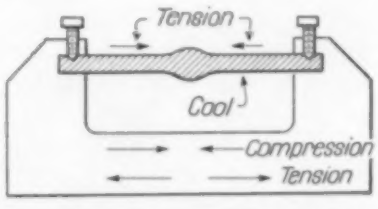


Fig. 5 — Cooling during end restraint from conditions in Fig. 4 throws tension into bar, reverses (and largely increases) bending stresses in base.

Fig. 1 to 5 — Effect of Localized Heat on a Bar of Metal Under Various Simple Conditions of Restraint

the bar after cooling, as shown in Fig. 4 and 5.

From the above, the following important points will be noted:

1. There will be no residual contraction or stress if the ends are free to expand and contract.

2. There will be no residual stress if the ends are free to contract.

3. There will be residual stress, but no contraction, if the ends are prevented from expanding during heat and from contracting on cooling.

In welding, these phenomena are essentially, but not exactly, the same. In practice, it is almost impossible to prevent some end restraint, yet the structure is not entirely rigid; therefore there will usually be some residual contraction and some residual stresses. These can, however, be kept within perfectly safe limits if the above principles, and the following, are understood, and measures are taken to counteract the undesirable effects.

Fig. 6 to 8 — Sequence of Welding a Simple Frame

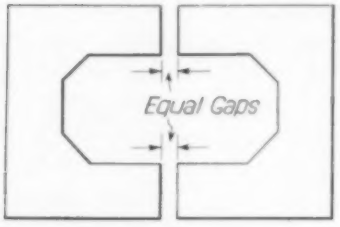


Fig. 6 — Parts set up with equal gaps at joints.

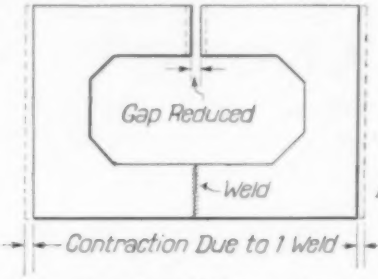


Fig. 7 — Conditions after one side is welded. Frame has contracted but no residual stresses exist (if weld is relatively short).

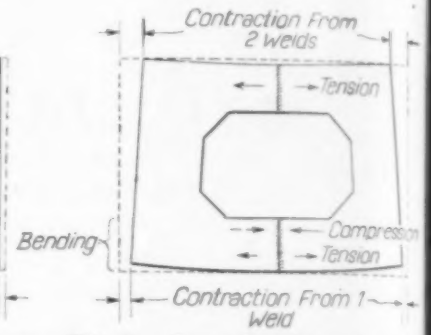


Fig. 8 — Second weld made under conditions of restraint and cooled. Considerable warping (contraction) and residual stresses caused exclusively by second weld.

In the following remarks it will be assumed that there is contraction at each weld, as is usual, owing to the progressive nature of welding, which is attended by restraint and upsetting due to the solidification of weld metal behind the arc. Figure 6 shows a simple structure prepared for welding. After one of the rather narrow legs has been welded, the conditions will be as shown in Fig. 7, that is one of the gaps will have been filled with hot metal rather quickly, and this metal will have cooled to ambient temperature, contracting during that period of cooling. The overall length of the structure will have contracted, but there are no internal residual stresses. Figure 8 shows the conditions after the second weld has been made. Heat effects will be similar to those shown in Fig. 4 and 5 in simplified form, and when the joint is cool there are residual locked-up stresses, and it will be noted that these are entirely due to the second weld.

This condition can be avoided by the procedure indicated in Fig. 9, 10, and 11. Strictly speaking, the wedge should be withdrawn half way before commencing the second weld, otherwise the cooled weld metal of the first few inches of the second weld would replace the wedge as a separator, and the stresses shown in Fig. 10 would partially remain, but reduced by the contraction of the second weld.

It has been noted that the stresses shown in

Fig. 9 to 11 — Procedure to Minimize Residual Stresses

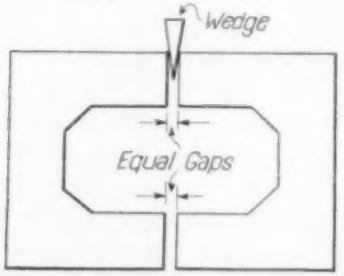


Fig. 9 — Set-up to prevent contraction of frame due to first weld.

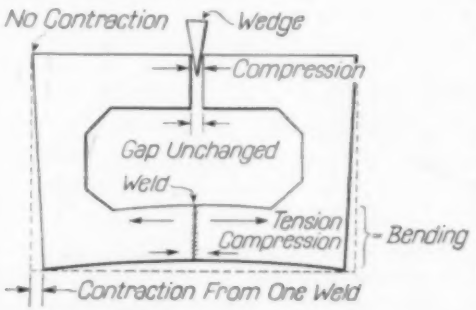


Fig. 10 — Conditions after one side is welded. Contraction forced in lower leg by rigid position of upper. Residual stresses opposite to those in Fig. 8.

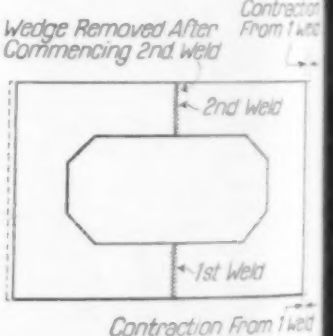


Fig. 11 — Second weld started, wedge removed, weld completed and cooled. Contraction due to second weld squares up frame and cancels residual stresses from first.

Fig. 10 are the opposite of those shown in Fig. 8, *i.e.*, they are the opposite of the residual stresses it is desired to avoid. It will also be noted that if a wedge were driven into the upper gap in Fig. 7 prior to making the second weld, it would produce the same sort of stresses as shown in Fig. 10. This observation is of extreme importance in considering the application of these principles to a large structure such as a ship. It leads to the conclusion that *the deck butts should be forced apart before welding.* This is the exact opposite of what usually happens in practice. The common practice is rather to pull the joints together, thus producing tension at the extreme opposite surface of the weldment instead of the desirable compression. This tension is added to the tension indicated in Fig. 8 caused by the contraction of the weld, and therefore the residual or locked-up stresses are increased.

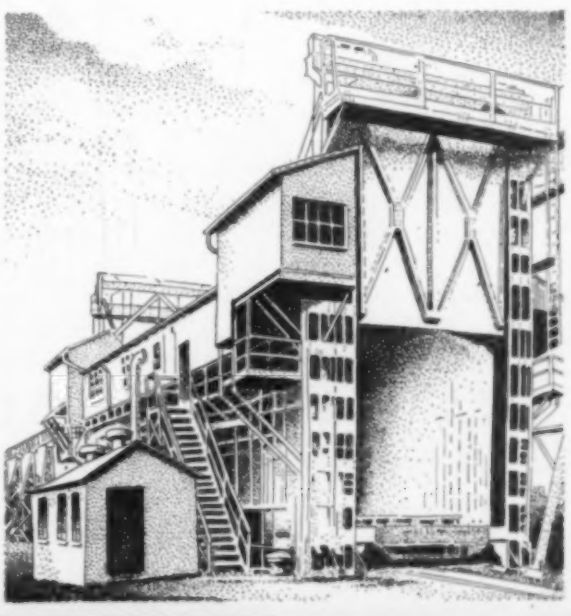
It can be seen from the foregoing that unless proper precautions are taken a welded ship can easily develop quite a heavy tension in the upper parts of the structure, such as the sheer strakes and decks. She starts life with this stress. A new ship, being light, is very commonly in a hogging condition (down at bow and stern, light amidships) which increases the tension in the deck. Again, a new ship, being launched, may not have all its machinery on board, which increases the hogging tension. Further, it may be that if tide conditions are not exactly right at launching she may "tip" — that is, pivot about the end of the ways — producing a further serious increase in the tension. Other circumstances tending to increase this tension are: Excessively cold atmosphere with a relatively warm sea; heavy weather, causing alternating hogging and sagging stresses; state of loading and ballasting. When, in addition, there are geometrical features of the structure tending to cause local concentrations of stress, there is real danger of failure.

It has been suggested, in discussions of locked-up stresses, that these tend to relieve themselves by local plastic deformations at the points where the stress is over the elastic limit. [EDITOR'S NOTE: See especially Robert T. Kinkead's exposition of this thesis in *Metal Progress* for June, page 924.] There is small comfort in this theory. It is fallacious for two reasons: *(a)* Plastic deformation only takes place at stresses above the yield point, and ceases when the stress is reduced to this point, so that stresses up to the yield point can remain in spite of the plastic deformation; *(b)* the extent of plastic deformation is dependent to a large extent upon the degree of restraint. In a narrow strip, such as a tensile test piece, plastic deformation takes the form of reduction in width and thickness, balanced by increase in length, so that the volume of metal is unchanged. In a large expanse of plate, the increase in length can only be compensated by reduction in thickness (not in width), and therefore fracture may occur at a much smaller elongation. [See also "Tri-Axial Stresses" in the same issue, page 946.]

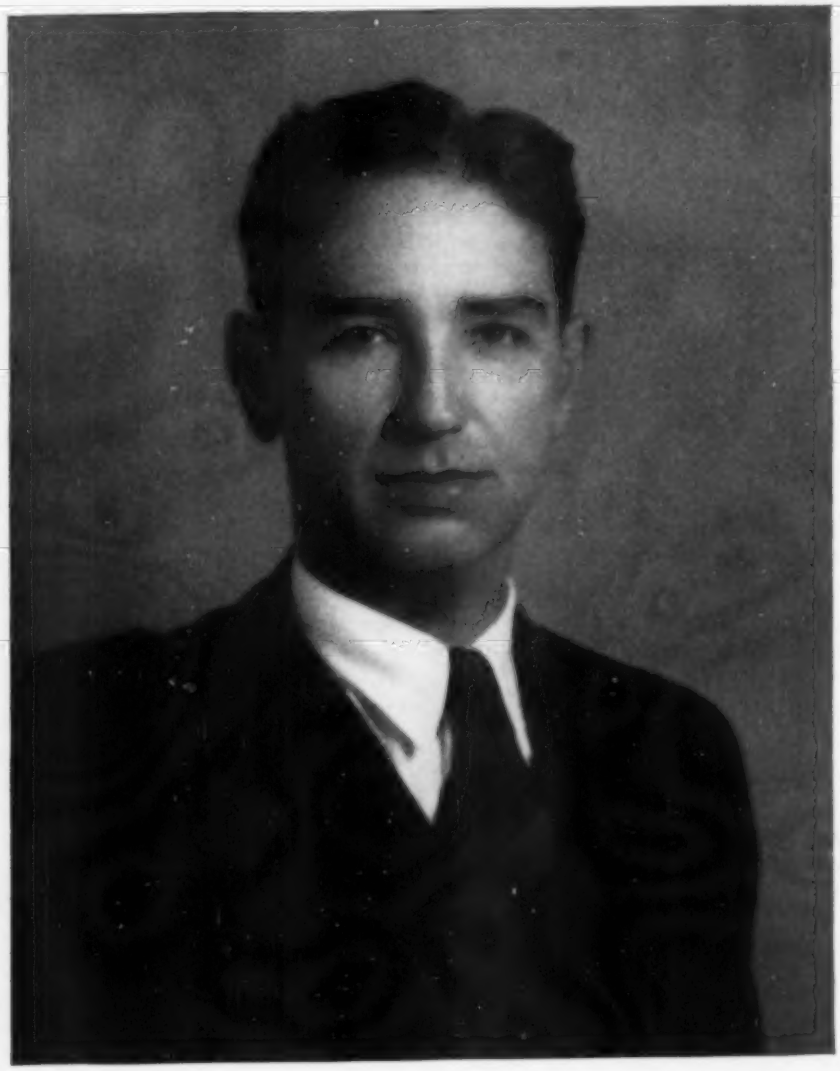
Nevertheless, plastic deformation due to overstressing does tend to equalize stresses, and is therefore helpful, but — a very important *but* — it cannot reduce the overall type of stresses likely to develop in large structures due to disregard of the precautions suggested above. Also, such attempts to equalize stresses by over-loading are attended by considerable danger of failure, especially in complicated structures.

The outstanding moral to be drawn from these observations is that locked-up stresses cannot be overlooked, but they can be avoided. It is essential that these fundamental principles should be widely and thoroughly understood, and fully appreciated, so that they can be intelligently applied. There is quite a widespread tendency to believe that contraction, distortion, and locked-up stresses are inherent and incurable defects, inseparable from welding. This can only be due to lack of understanding of the nature, causes, and cures. Much the same attitude was prevalent in relation to many diseases, such as small pox and other plagues, before medical science "debunked" them.

The tyro camper who goes to sleep leaving his tent guys tightly pulled up gets a graphic object lesson in locked-up stresses when his frail dwelling comes down around his ears during the first shower in the night. He might well be excused for considering this an inherent risk of camping, and he might even give it up on this account. The experienced camper leaves his guys slack, so that when the ropes shrink with the wet they will just pull taut — and sleeps peacefully.



A DISTINGUISHED METALLURGIST



Wesley Pope Sykes

EXPERT ON THE HEAVY METALS

ONE who attempts an introduction of WESLEY (BILL) SYKES to his fellow metallurgists may easily be considered to have undertaken an entirely superfluous task. Everybody knows Bill already!

Case School alumni know him, for he graduated there in 1916, received the degree of Metallurgical Engineer in 1920, and the honorary Doctorate of Engineering in 1934. He has lectured there on a regular schedule since 1934 and ever since his graduation taken an active interest in the affairs of his fraternity where he has counseled successive generations of his younger brothers.

The ⊕ knows him, for he was chairman of the Cleveland section in 1925-26 and has contributed voluminously and ably to its publications and programs, being the recipient of the Howe medal in 1927, as well as being the Campbell Memorial Lecturer in 1937.

The Japanese know him for he has crossed swords with them in debate, ably upholding the American viewpoint.

General Electric knows him for his work in the metallurgy of tungsten and molybdenum alloys. It shows its appreciation of its gifted employee by letting Bill go his own road in time and subject matter as few are privileged to do.

The Cleveland University Club knows him on the squash courts and as a connoisseur of the Club's refreshments.

Washington knew him for some months but Bill is now again home from the wars.

Many other technical societies know him as a member, to-wit the American Institute of Mining and Metallurgical Engineers, Tau Beta Pi and Sigma Xi.

This writer knows him in many of the preceding connections, and for a common interest in Gilbert and Sullivan and Gilbert Lewis.

And all of us who know Bill are also glad to know the charming Mrs. Bill, formerly secretary to Col. Leonard Ayres and now helping Case School with its training program for women in engineering.

One could write at length about WESLEY SYKES as a distinguished metallurgist, but prefers to write of him as a good friend and a good fellow.

HARRY A. SCHWARTZ

HEALTH ASPECTS OF WELDING

Abstract of pamphlet by A. G. Cranch and B. L. Vosburgh for National Safety Council, Inc., Chicago

IN SPITE of alleged hazards in welding, thorough studies have shown no excess of ill health among welding operators, or any outstanding type of illness among them. The real hazards are easily understood by any reasonably well-trained operator and means for protection are available and effective when used.

The real hazards peculiar to welding come essentially from radiation and from air contaminated by gases and fumes.

Radiation presents the hazard of intense light, glare and of ultraviolet exposures. In gas welding there is glare from too intense light. In electric arc welding there is also ultraviolet radiation. But in neither is there exposure to short waves like the X-ray. Workmen should be protected by suitable goggles, screens and non-reflective paint.

Hazardous gases may be essential to the type of welding (as the oxygen and acetylene in oxy-acetylene welding) or they may be produced through the reactions occurring in the welding process. Oxygen deficiency is not a factor if proper ventilation is arranged. Impurities in acetylene gas are not present in toxic amounts under present manufacturing methods.

Gases formed in the flame or arc are nitric oxide and other higher oxides of nitrogen. In the concentration present in welding they are a pulmonary irritant. Except in confined spaces no dangerous concentration would be likely to occur. The same is true of carbon dioxide, produced by the oxy-acetylene flame and by the electric arc; it is never generated in concentrations of physiological importance.

The metallic fumes of welding may come from materials being welded or used as a coating. Almost any metal may be melted by a welding operator and the fumes are a source of real hazard. The most common complaint is metal fume fever, and the most common source is zinc fume. Zinc should not be considered "highly toxic", however, as this condition is an acute, self-limiting reaction of short duration and without known after-effects or complications. But lead and cadmium fumes *(Continued on page 290)*

In this article, which is part of an address given before the Detroit Chapter ASM last winter, the thesis is argued that the machine designer should be most interested in that part of the fatigue curve (the S-N curve, so-called) which shows the cycles to failure at loads which give but limited life — above the endurance limit. Experience shows that this portion of the S-N curve becomes steeper as the test piece contains more intense stress raisers. Application of these considerations to design will be the subject of the final article next month

THE USEFUL DATA TO BE DERIVED FROM FATIGUE TESTS

By J. O. ALMEN

Research Laboratories Division, General Motors Corp., Detroit

WE STILL have far to go before we, as designers and producers of light-weight, dynamically loaded machines, can make full use of our structural materials. We must learn that we cannot tell the machine parts what they must do, but rather we must do as we are told by the machine parts. The rate at which we progress will, in large part, depend upon the accuracy of our interpretation of the complaints that are made to us by the machine elements. These complaints are not easily interpreted because they are often made in terms that we do not understand.

The conventional approach to studies of fatigue of metals is through laboratory tests on several arbitrary forms of fatigue specimens. During the many years that such tests have been made, a vast amount of fatigue data has been accumulated. These data have enabled us to formulate somewhat generalized "laws" on the behavior of various specimens subjected to repetitive stresses of several kinds.

We have found that steel, under most laboratory conditions of repetitive stress, has a fairly well defined limit of stress, known as the fatigue endurance limit, below which it will endure for an infinite number of stress cycles; and that the fatigue endurance limit of steel is roughly proportional to the ultimate strength of the material but that the proportionality varies with the range of the applied stress. We also know that, under certain other test conditions, steel does not have a fatigue endurance limit, that non-ferrous metals generally do not have a fatigue limit, that rough surfaces, notches, section changes and other discontinuities lower the fatigue strength. These and many other laws have been established through laboratory tests under controlled conditions.

The preferred laboratory fatigue test specimen is very carefully prepared to avoid all surface imperfections, abrupt section changes, internal stresses, and other stress raisers. This is considered necessary because the investigator is usually interested in the properties of the material undergoing test and he naturally seeks to eliminate all factors that would tend to obscure these inherent properties. There can be no objection to this procedure as it refers to the test specimens but the data thus obtained have little bearing on the fatigue characteristics of machine parts made from the same material and given the same heat treatment in which surface irregularities, abrupt changes in section and internal stresses are almost always present.

In presenting such fatigue data, the metallurgist may be likened to the seed catalog artist who paints the beautiful flower pictures that so arouse our gardening instincts every spring. The engineer is the gardener who hopefully plants the

seeds and who reaps the disappointments of his labors. The failure of the garden is usually not the fault of the seeds. The catalog pictures are intended to show what can be accomplished under favorable conditions and the artist should not be blamed for the poor garden soil, frost, drouth and the scores of other things that make the average garden look so unlike the catalog pictures. Similar disappointments are met when we attempt to apply the laboratory data on ideal specimens to the design of machine parts, more particularly for machines in which efficient use must be made of material under dynamic loading.

Economic Considerations

In the design of machines and equipment for heavy duty, where the number of units produced is small, the present practice of designing to large factors of safety is justified because the expense involved in preparing designs to approach the exact requirements would far exceed the savings in weight and material.

The same economic considerations that justify overdesign in low production volume equipment demand designs of low weight and high stress in many machine parts where weight is all-important, as in airplanes or in large production volume machines, such as automobiles, where both weight and cost must be considered. Obviously, the dynamically loaded parts of such machines should be designed with accurate knowledge of their fatigue strength.

When we try to apply quantitatively the accumulated laboratory fatigue data to such design problems, we find that they are almost useless. Published data on fatigue assume *(a)* that stress can be determined, *(b)* that laboratory test specimens are representative of a material when that material is formed into a machine part, *(c)* that the amount and nature of the applied load is known, *(d)* that load variations occur in an orderly and predictable manner, *(e)* that representative fatigue curves can be constructed from a dozen or less specimens, and *(f)* that machine parts must be stressed below the fatigue limit to be successful. These assumptions are not justified in practical design.

Stress Cannot Be Calculated

From the data on residual stresses that have been discussed in previous articles in this paper (*Metal Progress* for February 1943, page 209, and May, page 737), we may reasonably have some misgivings about the reliability of our stress calculations. From experience with practical machine parts we can only conclude that stress calculations by textbook methods are wholly inadequate until we generously temper our calculated results with experience. For example, crankshafts may be stressed by the usual methods of calculation to 20,000 psi., connecting rods are stressed to 40,000, valve springs to 90,000 psi., disk clutch springs to 180,000 psi., while another form of disk spring supports (by calculation) 600,000 psi. Obviously some of these stress values are ridiculous but the formulas used in each case conform to the "laws" of mechanics. The actual stress in crankshafts is probably several times 20,000 psi., while the 600,000 psi. in the disk spring is not reached because of yielding in local, highly stressed regions.

The unreliability of stress calculations has almost been forgotten by seasoned designers because they no longer take the numerical values of their stress calculations literally. Instead, they have learned by experience that, by the usual methods of calculation, the numerical values have different meanings for different machine parts; that is, somewhat rough empirical correction factors are applied.

There is a growing interest in various devices employed to make direct measurement of stress such as photo-elasticity, brittle lacquers, extensometers, and similar instruments in the belief that these devices will provide accurate stress data. The accuracy of stress data from such measurements is usually greater than can be obtained from the most involved mathematical analysis, but that they are far from reliable can easily be shown by fatigue tests.

Two specimens of identical material, heat treatment and dimensions will show identical stress when measured by photo-elasticity or by extensometer, yet these specimens may vary widely in fatigue strength depending upon minute differences in surface finish or residual stresses. Since residual stresses are often desirable and are frequently unavoidable due to processing operations such as machining, heat treating, straightening or grinding, and since surface finishes vary all the way from rough forgings to lapped or honed surfaces, there is little reason to expect accuracy from extensometer readings, and even less for photo-elastic tests since the specimens for this test must be free from residual stresses and must be made of another material.

Photo-elastic and extensometer readings are measures of elasticity in which the changes in dimensions are the statistical *average* of all of the material involved in the measurement. Fatigue tests provide a strength measure of the *weakest* portion of the material involved, usually

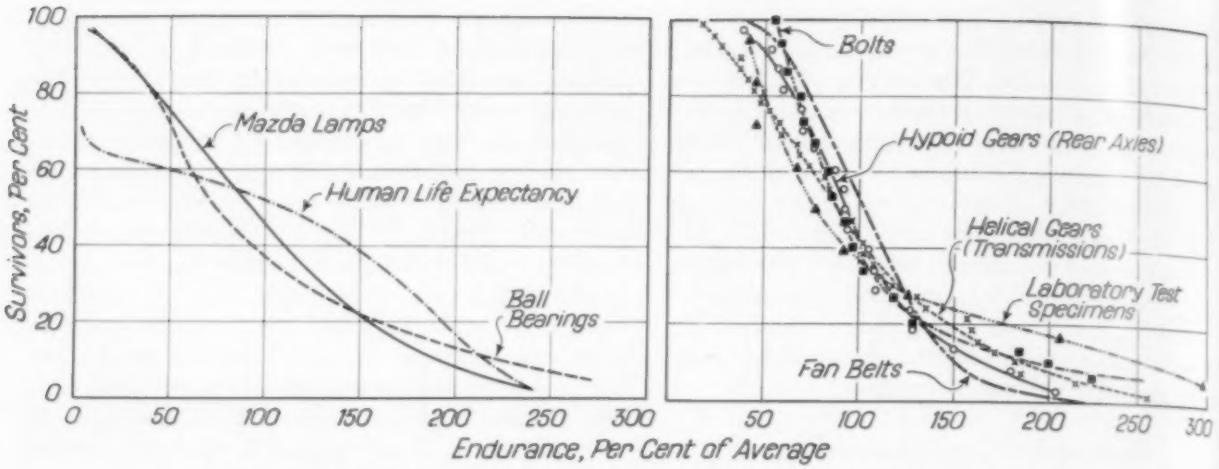


Fig. 1 and 2 — Life Expectancy Charts of Various Machine Parts Have a General Similarity, and May Be Regarded as Examples of Mortality Data

at the surface, even though it be sub-microscopic in size. Obviously, we cannot expect agreement.

Even if stress could be determined, the fatigue data from laboratory specimens could not be used because machine parts cannot be finished with the care and exactness that is given laboratory specimens. Abrupt section changes cannot be avoided, high residual stresses are often present as a result of processing or because of local heating as from bearing friction, and surfaces are subject to bruises and to corrosion of various kinds. These effects cannot be evaluated in terms of controlled stress raisers in test specimens.

Operating Loads Rarely Known

In the kind of machines under discussion, the dynamic loads are rarely constant for any appreciable time but vary up and down the load scale in an unpredictable way. Only a small percentage of the total number of stress cycles is at maximum load and this percentage will not be the same in the hands of any two operators. This brings up the question of damage by overstress (and recovery by understress) as has been observed by several investigators in tests of laboratory fatigue specimens. No doubt such effects occur also in dynamically loaded machine parts, but how are such laboratory data to be applied to machine parts when the schedule of overload and underload is beyond control?

This apparently hopeless situation is not, however, as hopeless as it seems. We have done a reasonably satisfactory job in the past without worrying overmuch about the shortcomings of the methods used. We may be certain that we will do better in the future as more experience is gained, and it is in the accumulation and organization of this experience that we can best serve the needs of the future. It is probable that fatigue studies will play increasingly important parts in future designs, but these studies will be based on fatigue tests of actual, full-scale machine parts instead of on laboratory specimens.

Fatigue tests of full-scale machine parts have been made by many laboratories for a long time but since these tests have usually been made for the purpose of comparing one material, design, or process with another material, design, or process, the tests have been run at arbitrary constant loads without thought to the fatigue curve characteristics and often without adequate correlation with service requirements. Because of this procedure, we have made little use of the vast quantities of such fatigue data which are now locked in our files, insofar as establishing a basis for evaluating material, design, or process for future use is concerned. In the few cases where fatigue data on machine parts have been properly organized, we find that they reveal astonishing amounts of fundamental information about the many variables that are present in machine elements, many of which are not even qualitatively revealed by ideal laboratory fatigue specimens.

Fatigue Data Are Mortality Data

Fatigue data are mortality data and it is just as absurd to expect that reliable actuarial tables can be constructed from mortality data on a half dozen persons as to expect reliable comparisons from fatigue tests on a half dozen machine parts. When a sufficient number of machine parts are fatigue tested at constant load and plotted in the manner of the well-known mortality curve for human life expectancy, we find remarkable similarity to human mortality experience. Heindlhofer and Sjvall in an article on "Endurance Test Data

and Their Interpretation" (*Mechanical Engineering*, Vol. 45, 1923, p. 579) have shown life expectancy curves for commercially identical ball bearings, for commercially identical Mazda lamps and for human beings. These curves are shown in Fig. 1 in which the ordinate is the percentage of units surviving and the abscissa is durability in per cent of average life.

Figure 2 is a life expectancy chart at constant load for commercially identical transmission gears in complete automobile transmissions, for commercially identical rear axle gears in complete automobile rear axles, for commercially identical automobile fan belts, for commercially identical bolts and for a group of ideal laboratory fatigue specimens. Similar life expectancy curves will result whether applied to mountain ranges or to the hairs on our heads. Although the general form of all life expectancy curves is the same, they differ in detail. Note that the expectancy curves for machine parts in Fig. 1 and 2 do not extend to zero life, as is the case in the human expectancy curve. Infant mortality is avoided in machine parts because the parts having a low potential life are rejected by factory inspection, a practice that is not followed for humans. Another important difference is the relative life span for various machine parts. Note that for automobile rear axle gears the life span of the most durable unit was about four times the life span of the poorest unit, but for automobile transmission gears the life span from the best to the poorest sample was about 15 to one. These test results show that the childhood mortality is much higher in automobile transmissions than it is in automobile rear axle gears.

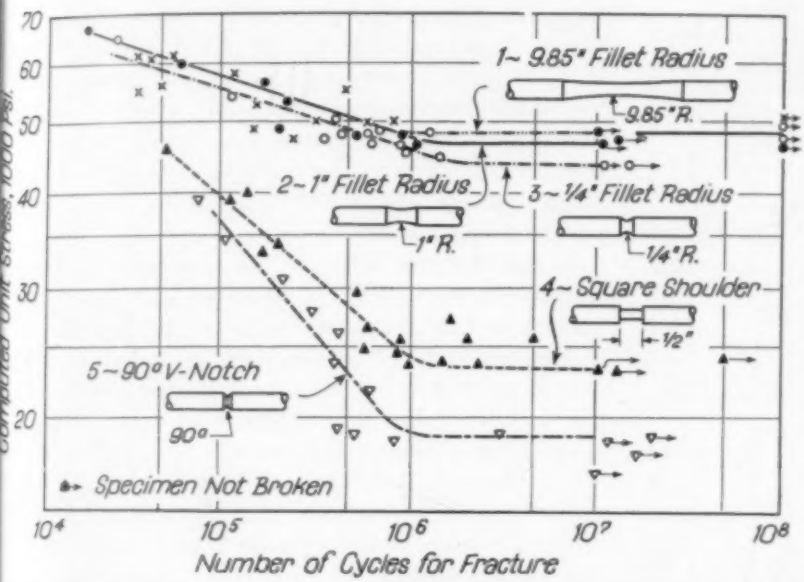


Fig. 3 — Moore & Kommers' Tests on Shape of Notch. 0.30-in. rounds of 0.49% carbon steel were water quenched and drawn at 1200° F. Diameter of reduced section is 0.275 in. in all specimens

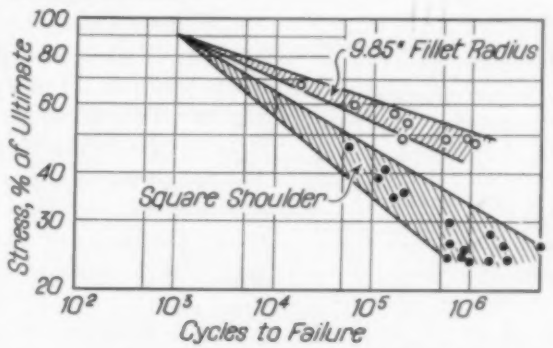


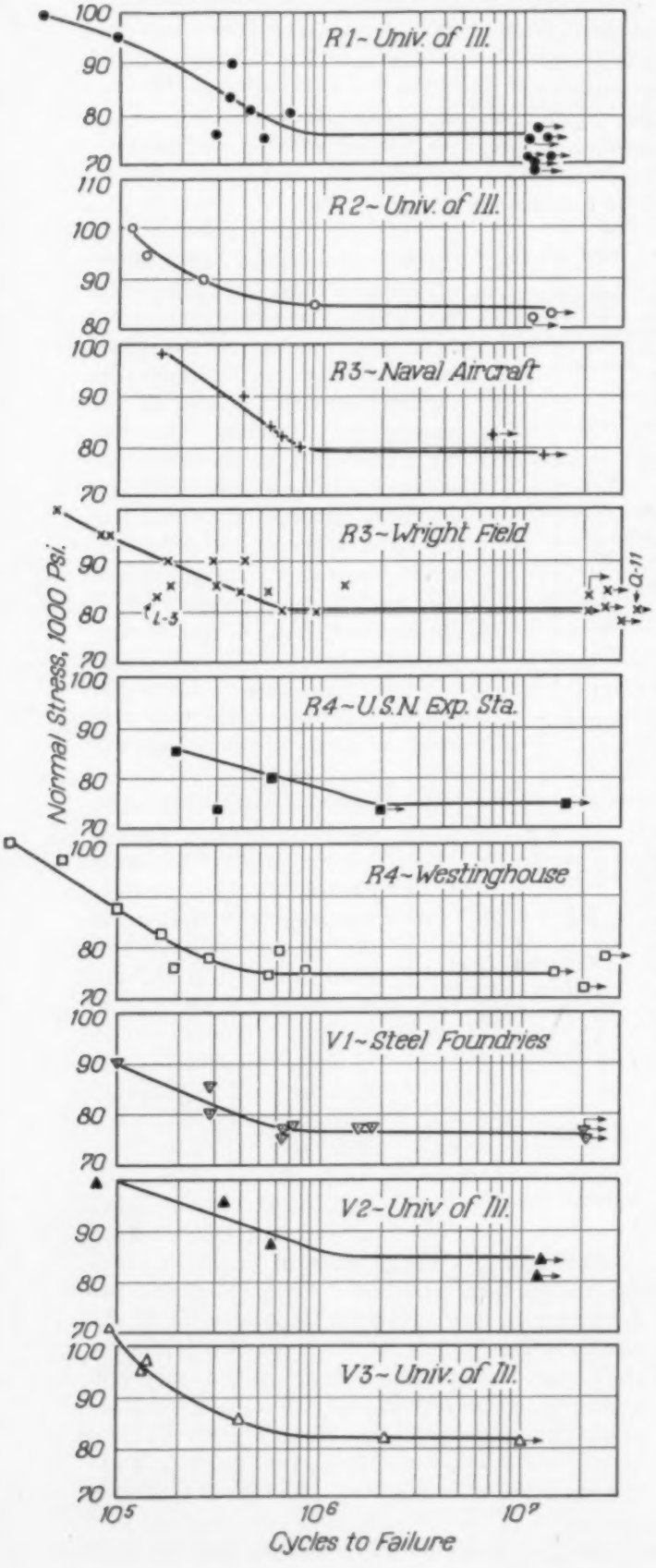
Fig. 4 — Data of Fig. 3, for Long Radius Fillet and for Square Shoulder, Plotted as Scatter Bands, Intersecting at a Point Near the Ultimate Tensile Strength of the Material (90,000 Psi.)

The life span ratios given above should not be taken literally because there are not enough test points in either curve to define their limits. As the number of test points is increased, the life ratio of the best to the poorest will increase but the "scatter" will be greater for transmission gears because, as normally cut, they have less tolerance for warpage and deflection errors than rear axle gears and they are, therefore, subjected to greater variations of stress concentration.

The percentage variation in life of machine parts will also change as the test load is changed. When tests are conducted at high load to produce fatigue failure after relatively few stress cycles, the percentage variation from the best to the poorest will be less than if the test is conducted at a lower load to produce fatigue failure after a relatively large number of stress cycles. The reason for this variable will become clear when we examine the form of the scatter band of adequate fatigue data.

Reliable life comparison of machine parts demands a large number of tests unless the life difference is very great. It is obvious from the mortality charts that, on the basis of a few tests, the poorer design, material, or process may rate higher than the better design, material, or process. Yet nowhere in the literature do we find fatigue data approaching even the minimum requirements of reliability. The reason is largely that most of the investigators in this field, particularly in work on steel, assume that we have

Fig. 5 — Selection of Data From an A.S.T.M. Cooperative Research, Wherein Several Laboratory Workers Determined the S-N Diagram of a Given Steel



no interest in data at any stress except the stress at which the specimen will endure indefinitely.

In practical testing of machine parts, it should be obvious that comparisons of material, design, or processing cannot be made unless the tests are run to failure and the comparisons are made on the number of stress cycles each will endure. This is true whether or not the part being tested is required to withstand, in service, a very large number of stress reversals at maximum load such as a crankshaft, or a relatively small number of stress reversals at maximum load, such as chassis springs. Since all representative tests are made at loads that result in failure by fatigue, our interest lies not in the fatigue endurance *limit*, where for steel, under most test conditions, life is infinite, but in that portion of the fatigue curve to the left of the "knee" where life is finite — that is, the sloping part of the S-N curve.

The characteristics of the sloping part of the fatigue curve have been obscured in most of the published S-N plots *(a)* by never having enough test points and *(b)* by the popular custom of plotting fatigue data on semi-logarithmic charts. In the very few cases where published data contain a considerable number of test points, we find that when plots are constructed on log-log charts the points tend to lie on a straight line instead of on a curved line, as is usual when they are plotted on semi-log charts.

Figure 3 shows a series of fatigue specimens used by Moore and Kommers (and described in their book on "Fatigue of Metals", published by McGraw-Hill Book Co.) to determine the effect on fatigue of varying degrees of stress concentration. The resulting fatigue curves, plotted on logarithmic coordinates, are also shown. The authors compare these specimens on the basis of calculated stress at the fatigue endurance limit; that is, the stress

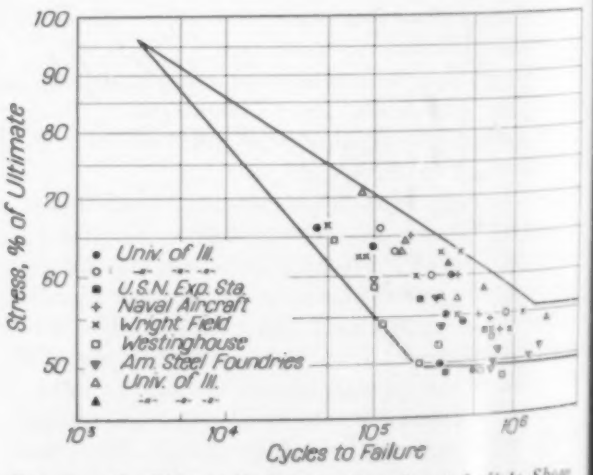


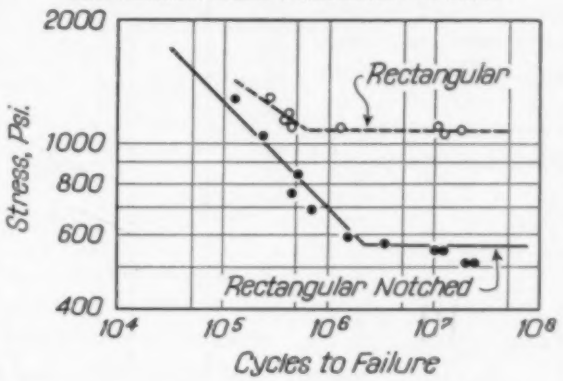
Fig. 6 — Re-Plot of Points in Graphs at Left to Show Scatter of Results at Loads Above Endurance Limits

at the knee where the curve becomes horizontal. However, as stated above, our interest is in the finite life region of the diagram; that is, in the characteristics of the curve lying to the left of the knee. Observe that as the notch severity of the specimen section is increased, the slope of the curve increases, and that the curves, if extended leftward, tend to cross one another.

Fatigue curves of machine parts, no matter how well they are finished or how carefully rejected for detectable flaws, almost invariably show steeper slopes than are shown by well finished fatigue specimens and, therefore, presumably the fatigue strength of a material as determined by ideal test specimens is not obtainable when that material is formed into a machine part. Permissible stress at the fatigue limit of a machine part may be less than 10% of the ultimate strength of the material, whereas laboratory test specimens may indicate 50% to be obtainable.

The difference in slope of fatigue curves suggests that this characteristic promises a way whereby we may eventually greatly improve our accuracy in determining the strength of machine parts. This is now being done in rating the load capacity of ball bearings, roller bearings, and automobile transmission and rear axle gears.

Fig. 8 — Findley Shows That Endurance Test Specimens of Cellulose Acetate Exhibit Same Tendencies as Steel



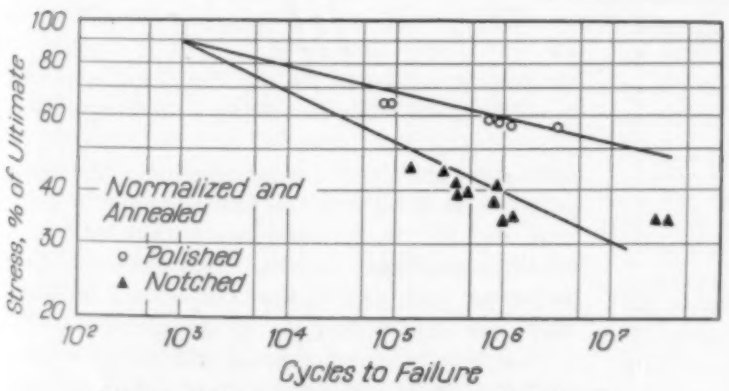


Fig. 7 — Oberg and Johnson's Tests (on S.A.E. 4134 Aircraft Steel, Normalized and Annealed) Designed to Show Influence of Notch

The lines plotted in Fig. 3 are intended to represent the averages for the specimens tested. Note the wide scatter of the test points and the increasing scatter of the points as the slope increases. Note also that, generally, the scatter decreases toward the left of the diagram. The significance of this scatter is not apparent in the diagram due to the limited number of test points, there being an average of only 12 failed tests for each type of specimen.

Scatter of Test Points

The scatter of test points is due to unavoidable differences in test specimens no matter how carefully they are made, and since these differences constitute varying degrees of stress concentration, the fatigue line representing the poorest of a group of specimens should lie on a steeper slope than the fatigue line representing the best of the specimens. This is for the same reason that the average slopes for the rotating beam specimens shown in Fig. 3 increase with the severity of the stress concentration due to shape of notch.

The test points for any group of specimens would, therefore, be expected to lie within a scatter band diverging from the region of high stress. The distribution of test points within this scatter band at any constant load will be of the order shown in Fig. 2.

If a sufficient number of specimens had been tested, and if the stress scale proportionality were the same for all specimens, it is probable that the sloped lines in Fig. 3 would all tend to converge toward a point in the vicinity of 1000 cycles and 90,000 psi., somewhat as indicated in Fig. 4. In this chart the fatigue slopes of specimens 1 and 4 of Fig. 3 are shown as converging bands rather than lines. This region of intersection is suggested because the ultimate strength of the material tested by Moore and Kommers was approximately 95,000 psi. and, obviously, if the stress scale is correct for each type of specimen, they would all withstand approximately the same stress at one stress cycle. The point of intersection would probably be at a considerable number of stress cycles because the ductility of the material permits adjustment of stress through yield, thus reducing the influence of local highly stressed points. For very brittle material, the intersection point of the fatigue curves for the

type of specimens shown in Fig. 3 would probably be near the ultimate strength and nearer one cycle of stress.

There are not now available sufficient data on any specimens to complete a group of fatigue diagrams to the region of intersection. Knowledge of the characteristics of fatigue curves at high stress would be valuable in industry since it would greatly facilitate interpretation of fatigue tests on machine parts. Such tests could be evaluated in terms of the slope of the fatigue curve, which would also give a clue to the actual stress, if desired, in the part being tested.

Apparent Disagreement of Test Data

The research committee on Fatigue of Metals of the American Society for Testing Materials recently sponsored a cooperative test program in which several laboratories conducted independent fatigue tests on identical material (heat treated S.A.E.4340) under similar test conditions. The results were reported in an A.S.T.M. research

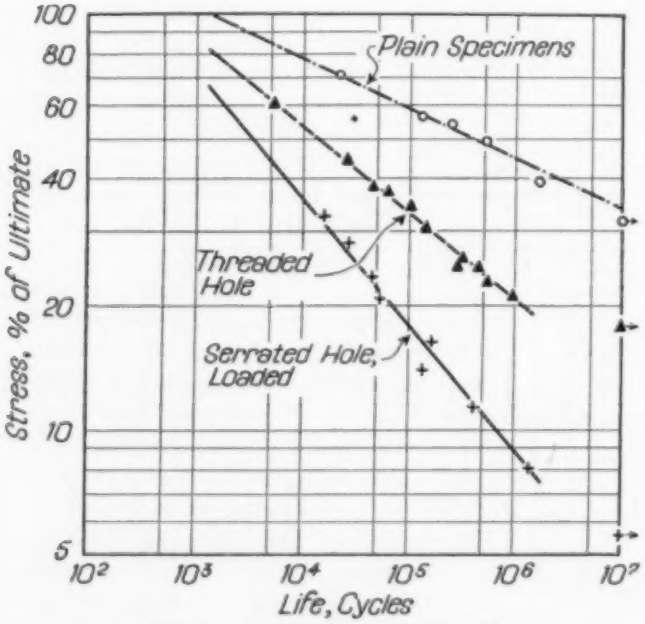


Fig. 9 — Fatigue Tests on Duralumin, Re-Plotted on Log-Log Scale

report presented at the June 1941 annual meeting, and from this the group of plots shown in Fig. 5 is taken. Note the wide disagreement between the curves from the several laboratories in the fatigue limit as well as in the sloping part of the curves. When all of the 59 individual failed points are plotted on a log-log chart, as is shown in Fig. 6, we begin to see a semblance of order. All of the points lie within a scatter band of the same converging form that is shown in Fig. 4.

In passing, it is interesting to note that in Fig. 5 we find 9 test points at 85,000 psi. load which are the points plotted in the life expectancy curve, Fig. 2, to show that the life variation of laboratory specimens is of the same order as the life variation of gears and other machine parts.

Published data on fatigue of metals contain numerous tests showing the same general trend of increasing slope with increasing stress concentration whether due to differences in specimen shape, specimen size, mechanical working of specimen surface, surface coatings, fillet radii, surface finish, or to unavoidable variations

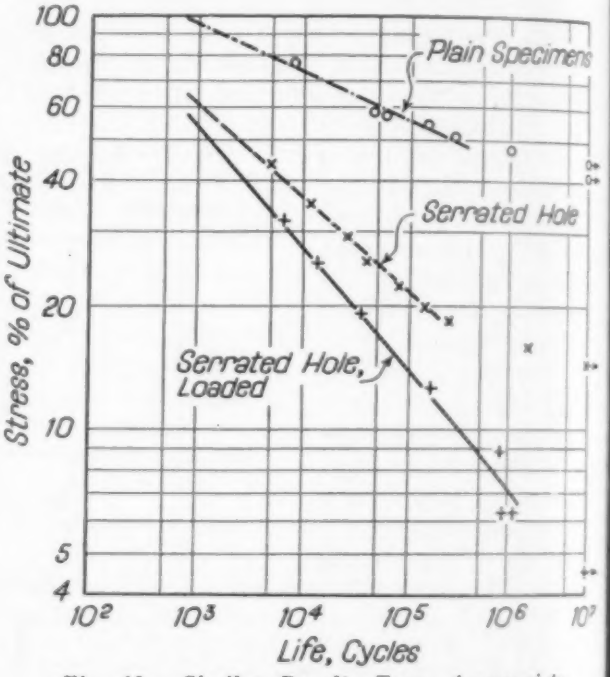


Fig. 10 — Similar Results From Appropriate Tests on "Electron", a Strong Magnesium Alloy

between "identical" specimens. As previously stated, this tendency toward convergence is seldom apparent in the published curves because the investigators have plotted their data on linear ordinates and logarithmic abscissas and always there are insufficient test points.

A few other diagrams will now be given, replotted from published data, to the same scale as Fig. 4, in which the stress scale is four times the scale of stress repetitions. The slopes of the curves are calculated as the measured horizontal distance multiplied by the scale ratio divided by the measured vertical distance. (Note that this is the reciprocal of the slope as ordinarily used in engineering but it is a more convenient form for our purpose.)

T. T. Oberg and J. B. Johnson report in the *Proceedings* of the American Society for Testing Materials, Vol. 37, Part 2, 1937, page 199, a comparison between polished and notched specimens.

This is shown in Fig. 7 with results similar to the experiments by Moore and Kommers shown in Fig. 3.

Surface treatment of the test specimens other than the degree of smoothness has a marked effect on fatigue strength. In a paper on "Increasing the Fatigue Strength of Press-Fitted Axle Assemblies by Surface Rolling (*Transactions*, American Society of Mechanical Engineering, Vol. 58, 1936, p. A-91), O. J. Horger and J. L. Maulbetsch compared normal well-finished specimens with specimens that had been subjected to a rolling operation which introduced compressive stresses in the surface layer. The rolled specimens showed considerably better endurance, as shown in Fig. 3 of the first part of this paper (February *Metal Progress*, page 212).

Since the rolled specimens were pre-stressed in compression the subsequent tension stresses during the test were reduced as is shown in Fig. 6 of the February article, page 213; hence the difference in the slope of the curves for the two types of specimens. Since this treatment would be ineffective in a tensile test the lines should converge in the manner shown.

Tendency Persists in Other Materials

When replotted on log-log charts, published fatigue curves on other materials than steel exhibit the same tendency to converge toward the left and to increase their slope as notch effects are increased.

W. M. Findley, in *Modern Plastics*, Vol. 19, 1941, page 57, described fatigue tests on cellulose acetate specimens with the replotted results shown in Fig. 8. As is usual there are not as many test points as are needed to define the region of convergence but the trend is definite.

Fatigue tests on duralumin, Fig. 9, and magnesium, Fig. 10, in plain and various notched specimens were reported by H. Burnheim in *Luftfahrtforschung*, Vol. 19, No. 2-3, March 1941. These re-plotted charts are more satisfactory than most published data in that the region of convergence is more clearly defined.

From the foregoing it seems reasonable, as a working hypothesis, to assume that, except possibly for very ductile metals, the slope of the fatigue curve, as measured on a log-log plot, may be considered a measure of effective stress and that the fatigue curves for varying stress concentrations converge toward a point near the tensile strength of the material and at some considerable number of stress cycles. In an article in next month's *Metal Progress* it will be shown how these ideas can be utilized in practice.

THIN CASE HARDENING WITH RADIO ENERGY*

By VERNON W. SHERMAN

INDUCTION heating of metals was patented over 50 years ago, and is commonly used at present. The principal frequencies now used for melting, preheating, and annealing are generally below 12,000 cycles. For surface hardening of relatively large parts where considerable depth of case can be permitted, frequencies up to 12,000 are of value. For thin case hardening (0.005 to 0.030 in.) frequencies above 500,000 cycles are indicated; in fact, the author recommends 5,000,000 to 15,000,000-cycle energy.

When an iron cylinder is placed within the turns of an induction heating coil, energized with alternating current, heat is developed in the iron part. A high rate of energy input for a short time interval is required to restrict heating to a controllable surface layer — for the following reasons:

When the turns of the induction heating coil enclose an iron cylinder, a transformer is created whose secondary is the short-circuited surface layer of the iron cylinder. The current I which is induced into this secondary flows through a resistance R and develops heat at a rate that in watts is equal to I^2R. This is the mechanism whereby electrical energy is converted into heat energy.

In a particular induction heating coil there will be a finite number of turns, such as ten, and through these turns the equipment will drive some definite current, such as 100 amperes. There is then available for heat-treating purposes a 1000 ampere-turn primary. Since the secondary consists of one turn, its theoretical maximum current cannot exceed 1000 amperes.

Because of the need for insulation and mechanical clearance, the secondary will be spaced somewhat away from the primary and therefore not all of the primary flux will thread the surface of the work. If only 50% of the primary flux links with the *(Cont. on page 294)*

*Summary of article by Vernon W. Sherman, Manager, Industrial Electronics Division, Federal Telephone & Radio Corp., entitled "Thin Case Hardening with Radio-Frequency Energy", *Aeronautical Engineering Review*, June 1943.

CRITICAL POINTS

By THE EDITOR

Random observations, mostly about ships, passed by the Navy's Censor

ACQUIRED many new ideas at the annual meeting of the American Society for Testing Materials in Pittsburgh, and also advanced some of my own which were not unanimously and enthusiastically accepted — all of which is as it should be and is the common experience of those fortunate enough to attend such gatherings. Sharply reminded of the passage of time, however, by comparing a "symposium" on the hardness test — a rather dull rehash of information about what the test really tests, rescued by some trenchant remarks by Bureau of Standards' Dr. TUCKERMAN — with another held by the infant American Society for Steel Treating certainly 20 years ago, where those present were eager to discuss the commercial and practical possibilities of the "new" Brinell test. In another meeting, R. G. STURM of Alcoa Laboratories acted as advocate for a little liked property of metals, noting that whereas there are two bad things about creep, since a metal part under high stress may grow too big for its clearances or may become inadequate for its load and buckle, yet there are two good things of far greater significance: First is that creep enables metal to relieve stresses at internal and surface "stress raisers", and second is that creep equalizes the stresses in such things as walls of drums and pressure vessels. Notable at this session were the papers by Westinghouse's NADAI and MCVETTY showing how a series of creep tests on a single metal at a limited number of times, temperatures and loads, could be resolved into a system of interpolated data from which the designer could predict the expected action of a definite part under a given tensile stress and a certain temperature. In this respect the students of creep are away ahead of the fatigue testers, for OTTO ALMEN's recent articles in *Metal Progress* show how tenuous is the relation between the endurance of an ideal laboratory specimen and of a moving machine part.

Hardness, creep and fatigue

WOOD as an engineering material was considered by the Marburg Lecturer at that same A.S.T.M. meeting — L. J. MARKWARDT of the Forest Products Laboratory at University of Wisconsin. This would have been no news 40 years ago, but in the intervening time steel has all but supplanted timber except in quite temporary structures — a trend temporarily halted by war shortages of metal. MARKWARDT cited several reasons why this self-renewing natural resource could retain these recent gains, such as improvements in joint designs, structural grading of timber, chemical seasoning and new preservatives. Water resistant glues have done much to improve plywoods and widen their utility. Especially interesting are the combinations of wood, lignin (a wood product) and phenolic plastics. It is possible to impregnate these resins into the wood cells, compress the material, polymerize the resins by heat, and a dense, strong substance emerges, a third again as heavy as water, having 43,000 psi. tensile strength and a modulus of 4½ million — certainly the characteristics of an engineering material.... This combination of organic and synthetic material brings up again some thoughts on plastics — those ubiquitous and multifarious substances that hold unforeseen possibilities — and remembered what JOHN TOWNSEND of Bell Telephone Laboratories said recently about an improvement in heating technique of thin objects like Victrola records that ranks with one of the month-by-month "revolutions" in the plastic industry.

Wood & plastics

Resins of phenol and formaldehyde of the Bakelite family have been at a disadvantage to the thermoplastic materials because the latter "set" so much more rapidly, thus speeding the manufacturing operation, reducing die costs and forming pressures. Now the bakelite powders are pressed lightly into a compact, the latter placed in a high frequency electric field between two plates and heated to a butter-like consistency, then transferred to restriking dies where polymerization is completed in 5% of the time formerly necessary.

The Navy studies detectors

To Anacostia, D. C., to attend the 20th birthday of the Naval Research Laboratory, expanded recently at a prodigious rate, and glad to find Lawrence Addicks — member of Thomas A. Edison's original Naval Consulting Board of 1916 — still active on that advisory committee. Anacostia's achievements in underwater sonic detection of submarines and in accurate radio location of surface warships and aircraft were praised by James Forrestal, Under Secretary of the Navy, and Capt. Thomas Gatch, commanding officer of one of the battleships in the Solomon Islands fight. Charles F. Kettering emphasized that these developments were the product of years of effort by hundreds of men in dozens of laboratories — radar, for example, stemming from experiments about 25 years old. He also pointed out a fundamental difference between naval research and commercial research: In industry the value of a new development does not accrue until everybody knows and uses it; new war matériel, on the other hand, is of value only as long as it is secret.

Impact test on welded armor

Hence practically nothing can be said about the activities of the physical metallurgy department, headed by Francis Walters, Jr. (Since the open house the Censor has asked all Editors to refrain even from mentioning the name of one of its important sections!) One interesting recent item can be outlined, a quick test for quality of butt-welds in armor plate that checks the proving-ground results on "H" plates illustrated in *Metal Progress* last March. Samples 1½ in. wide are cut across the joint, fixed vertically, and struck by a blunt-nosed 50-caliber slug 2 in. above the centerline of the joint. Velocity of the bullet that cracks the joint in this impact test is a measure of the weld's quality....Three problems, important to all arms, are stalled at the very beginning: Wanted is an inexpensive metal suitable for tableware. Wanted is a method for rustproofing steels, a step out in front of the phosphate bonderizing. Wanted is a simple, non-toxic process better than painting for darkening aluminum and stainless so they don't reflect light. Any ideas?

Battleship manufactory

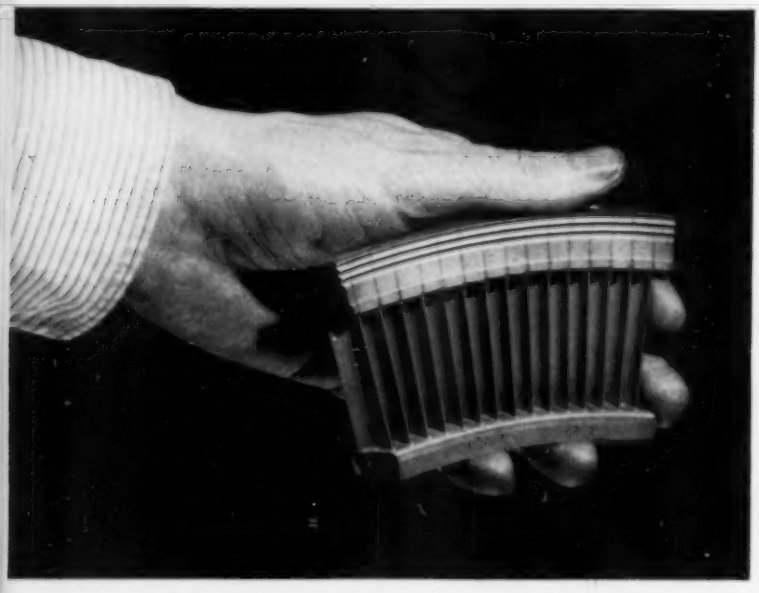
To Quincy ("Quinzy Mass" to the natives), site of Bethlehem Steel Co.'s enormous Fore River Shipyard, as well as another equally large sprung up since early 1942, and greatly cheered by the sight of so many aircraft carriers, heavy cruisers, and destroyer escorts in all stages of construction from keel laying to last touches in fitting-out basins. Fore River Yard builds nothing but the heavier warships, and it is strange to see, in the turret shop, these great armored cylinders — three stories high and jam-packed with mechanism — assembled in a real production line 200 yards long.

Welding— castings, stern frames, "drumhead"

Discussed with Paul Ffield, materials engineer of Bethlehem's Shipbuilding Division, many problems connected with welding of structures and repair welding of castings. His organization pioneered many years ago the plan of casting the carbon-molybdenum steel housings for steam turbines in three pieces and welding them together rather than casting them in a unit, thus molding and gating each portion in a way best suited to its shape and mass, rather than attempting a compromise on a bigger piece. So the Yard was ready for the difficult welding of intricate stern frames, and the expert use of strip heaters for local preheating, and their final stress relieving in a furnace bigger than a house....What word, though, can describe politely the treatment a light bulkhead gets in "drumhead" welding? The plates are laid out on the flat steel floor of the "steel mill" (shipyard's name for plate shop), tack welded to the floor around the outer edges of the assembly, and then the butts and stiffeners welded in such a way as to stretch the bulkhead toward its center until the anchorage all but snaps. To take out remaining buckles, numerous spots are heated with an oxy-acetylene flame; the expanding metal in the center of the hot spot upsets, and on cooling draws tension into the sheet. Don't let anyone tell you that the ordinary or garden variety of steel that can survive this ordeal is "below quality", no matter what the specification says.

BRAZING of turbine blades into segments of 10 to 15 has been successfully done at Fore River Shipyard for years, and illustrates some metallurgical fundamentals: First it was found that the 13% chromium stainless steel contained enough nickel and molybdenum that there was a transformation at about 500° F. when cooling after brazing, changing the volume enough so the brass in the joints would crack, it being weak in precisely that temperature range. So a dilatometer test was inserted in the specifications, to the dismay of steel makers, but met readily by an analysis without tramp alloys. Next it is necessary that the parts be *clean*, so after machining they are dangled by their tip ends from a magnet, dunked in an electrolytic pickle, and the resulting brown smudge is scoured off in a wet shot blast. Correct preheating and brazing of the bases into one rigid segment is done with the help of a cam-operated lever; the segment, riding in a wire cradle, is immersed in the thick layer of molten flux deep enough and long enough so the metal is properly preheated, then lowered automatically an inch or so further so the bottom dips into the molten brass below, and metal is immediately sucked up into the joints by capillary action.

Brazing stainless assemblies



HARDLY through the door of the first shop at Dominion Engineering Works in Montreal, chanced upon an instance where castings were replacing forgings and no one much to blame but the forge shop. Suppose you were making steam engines for Liberty Cargo Ships and were getting rough forgings (and I'll say they're rough) weighing 3800 lb. which ultimately machined down to 1500, and found you could get steel castings weighing only 2350 lb., suitable for the same service and saving 35 to 50 machine-hours of time in finishing. Would you hesitate which one to choose? "Oh yes," you'd say, "but how about the physicals?" Well, the marine inspection and insurance companies are not so much interested in strength of connecting rods as in plasticity—in fact there is a maximum and minimum specified on ultimate, and a minimum on elongation. Composition of the castings and the forgings is about the same (C 0.30%, Mn 0.75%, Si 0.25%) except that silicon in the castings is somewhat higher; elongation in 2 in. is a little less (30% in place of 35% for the forging), but there is little or no difference between longitudinal and transverse directions in the cast rod. Izod impact of the annealed forgings varies from 25 to 60 ft-lb., corresponding to whether the grain size is coarse or fine; for the castings it ranges around 35, they having a relatively fine grain size from their heat treatment: First, air cool from 1650° F., and then air cool or furnace cool from 1525° F., depending on analysis. . . . Now which one would you choose?

Castings replace heavy forgings

EWING TAIT, metallurgist for Dominion and currently chairman of Montreal Chapter, also showed me a testing set for large worm gears, by means of which he is searching for a substitute for phosphor bronze. The equipment includes a commercial gear box equipped with over-size roller bearings, wherein a casehardened and polished worm is direct connected to an electric motor. The gear to be tested is accurately fitted and connected to a friction brake. In starting the test the combination is adjusted to transmit 2 hp. at standard speed, and a time-temperature curve of the lubricating oil is plotted. This rises to a certain degree and then stands stationary. When everything is in equilibrium, the load is increased. Eventually a load is reached where the temperature rises continuously, which is evidence of seizure. Phosphor bronze in this set will regularly transmit 4¼ hp. A 90:2:8 Cu:Ni:Sb alloy developed by CHESTER B. HAMILTON of Hamilton Gear and Machine Co. of Toronto will do just about as well. The same might be said for an aluminum bronze (10% Al, 4% Fe, 1% max. Mn). Nothing else has yet approached 4¼ hp., representing a heavy load transmitted continuously. Representative silicon bronzes, for example, will carry from 2 to 2½ hp.

Testing heavy worm and gear combinations

In an attempt to bring a greater degree of precision into Buick's carburizing operations, particularly for thin cases of definite carbon contents at the surface, some data sheets containing definitions, derivations of formulae, information about gas circulation and available carbon were constructed, and they led to a series of experiments which established some standards for the carburizing process, and a table showing practical case depths under normal conditions for a wide variety of times and temperatures — which are also applicable to diffusion cycles.

"CASE DEPTH"

— an attempt at a practical definition

By F. E. HARRIS

Furnace Engineer, Buick Motor Division, General Motors Corp., Flint, Mich.

CARBURIZATION, even though it was the earliest of all metallurgical operations to be studied from a scientific standpoint, is today practiced commercially under the most diverse conditions. There is reasonable agreement that 1700° F. is close to the optimum operating temperature, but great variation exists in the carburizing medium (solid, liquid or gas), the analysis of the steels being carburized, and the post treatment comprising quenchings, reheatings and diffusion treatments. Recently published items in *Metal Progress's* department "Bits and Pieces" indicate that metallurgists do not agree upon a commercial method of evaluating the result of the process, and prove that the commonly used term "case depth" has no precise significance. It is therefore timely to attempt a more scientific approach to the problem of accurate control, even though it will require the reader to get acquainted with some abstractions, and applications of the laws of physical chemistry.

It will be the aim of this paper, therefore, to analyze some simple operations — commercial carburizing cycles supplying sufficient carbon at all times to satisfy the demands of the various carburizing steels tested — adhering strictly to the scientific fundamentals as they are known to us. In other words, the experiments showing the carbon concentration at various depths in a sample steel will be related to data on the solubility of carbon in austenite and its ability to diffuse therein. It will appear that the result will be substantially constant for all the steels tested, independent of chemical specification or grain size, and therefore capable of being developed into a standard for the evaluation of the carburizing process. Equally valuable will be its application to diffusion treatments, because the control of carbon gradients by carburizing-diffusion cycles is important commercially and requires a close regulation of the operating conditions. Another important by-product will be means for controlling the inverse process, namely, decarburization of a steel's surface during heating for quenching, annealing, or other purpose.

Experimental Procedure

The basic experiments consisted of three runs made at temperatures comprising the practical carburizing range: 1600, 1650, and 1700° F. Each run includes samples, ground on centers to 1.000 ± 0.001 in. diameter by 6½ in. long, of carburizing steels of varied analyses — S.A.E. 1020, 2515, 3115, 4320, 4620, 4820 and NE8620 and 8720. A 25-in. diameter by 36-in. deep Leeds & Northrup Homocarb furnace was employed, with gas flowing at standard and constant rate throughout each cycle, and within which samples were hung vertically from a fixture. All three runs were of 8-hr.

Table I — Log Sheet of Furnace Runs

Time	Temperature	Gas				Remarks
		Pressure *(a)*	CO_2 *(b)*	Gas Flow, Cu.Ft. Per Hr.		
				Natural Gas *(c)*	Drycolene *(d)*	
			Run No. 1 at 1700° F.			
9:15	1600° F.			12	55	Test plugs charged
9:20	1620	0.70	2.0%	12	55	
9:25	1680		0.6	12	55	
9:30	1710	0.44	0.0	8	55	Input at 15% *(e)*
1:00	1700	0.40	0.0	8	55	Input at 20%
4:45	1700	0.62	0.0	8	55	
5:15						Test plugs pulled
			Run No. 2 at 1650° F.			
8:15	1575° F.			12	55	Test plugs charged
8:20	1605	0.70	4.0%	12	55	Input at 20%
8:25	1650		1.4	12	55	
8:30	1650	0.53	0.0	8	55	
1:00	1650		0.0	8	55	
3:45	1650		0.0	8	55	
4:15						Test plugs pulled
			Run No. 3 at 1600° F.			
8:10	1600° F.			12	55	Test plugs charged
8:15	1575	0.70	2.8%	12	55	
8:20	1600	0.70	0.0	8	55	Input at 20%
3:45	1600	0.58	0.0	8	55	
4:10						Test plugs pulled

(a) Pressure at top of furnace in inches of water above atmospheric.
(b) Analysis of effluent.
(c) 79% CH_4, 8% C_2H_6, 4% C_3H_8, 9% N_2.
(d) 22.7% CO, 2.2% H_2, 75.1% N_2.
(e) Electrical heating input (Lindberg control) in % of max. kw.

duration, the log sheets being as shown above.

On the day preceding the first run the furnace was brought to 1600° F. during the afternoon and held all night, purging constantly with a mixture of 4 cu.ft. of natural gas and 55 cu.ft. of drycolene (hourly consumption). Overnight — between runs — the furnace was held at temperature, with 2 cu.ft. of natural gas and 55 cu.ft. of drycolene per hr. constantly passing through.

Carburized samples were air cooled, notches cut 5⅛ in. apart, and the intervening surface turned down by 0.005 stages, samples collected and analyzed. Results for NE8620 are given in Table II (space limitations crowding out similar data for the other steels), but they are all plotted in the curves shown in Fig. 1 to 8, page 272A.

Mechanisms and Methods

Before evaluating the experimental data, various methods of simplifying the theoretical problem will be given.

It will be assumed that the conception of "normal carburizing at a given temperature" will involve the establishment of saturated austenite at the steel surface. This does not occur immediately, for the cold steel must be brought to temperature, and its very surface layer must absorb as much carbon as it can by virtue of its temperature and content of alloy and incidental elements. Time at which carburizing starts is, therefore, that time when the stock has reached temperature, or that time when the effluent gases show no CO_2, whichever is the longer. Table I shows the time to reach zero CO_2 is 10 to 15 min. In these experiments, allowing another 15 min. to reach equilibrium, we take 7½ hr. as the "normal carburizing period", that period for which, at a given temperature, the carbon concentration maintained at the steel surface represents the saturated solution for a given steel analysis.

The actual carbon concentration at the surface is a function of temperature and steel specification. This carbon, constantly renewed, diffuses inward toward metal of lower carbon content. The depth of penetration and the carbon content at any depth below the surface at the end of the process, after any known time, should be capable of calculation if we have sufficiently accurate

Table II — Carbon Content of NE8620 Samples (Base Carbon 0.22%)

Cut	Carburizing Temperature		
	1700° F.	1650° F.	1600° F.
0.000	(1.31)	(1.24)	(1.18)
0.005	1.23	1.26	1.18
0.010	1.21	1.10	1.04
0.015	1.14	1.04	0.96
0.020	1.06	0.93	0.84
0.030	0.94	0.79	0.66
0.040	0.74	0.58	0.48
0.050	0.58	0.44	0.34
0.060	0.43	0.31	0.29
0.070	0.33	0.25	
0.080	0.27	0.21	
0.090	0.24		
0.100	0.24		

knowledge of the physico-chemical laws of diffusion, and a knowledge of the diffusion "constant".

The diffusion constant D (or "diffusivity coefficient") is defined as the amount of a substance in grams diffusing in 1 sec. across an area of 1 sq.cm. through a unit concentration gradient. The principal variable that increases its magnitude is, of course, temperature; the higher the temperature the more rapid the diffusion. Another factor, in the case of austenite, is the "pressure head" or local concentration of carbon. For the present we will assume that the diffusion constant is independent of composition of the austenite in alloys other than carbon, or its grain size.

The theoretical relation between diffusion "constant", carbon concentration, and depth after any elapsed time is given by the so-called Fick law of diffusion, which may be written

$$\frac{dc}{dt} = \frac{d}{dx}\left(D\frac{dc}{dx}\right) \qquad (1)$$

a differential equation wherein

c denotes concentration of carbon at any given point

t denotes elapsed time

x is the linear distance of the given point below the surface of high concentration

D is the diffusion "constant".

Neglecting, for the time, the relatively small variation of D with the amount of carbon existing at the spot under consideration, the solution of this equation for a semi-infinite solid, where a saturated concentration, c_o, is maintained at the surface, is expressed by

$$\frac{C}{C_o} = 1 - \frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{Dt}}} e^{-y^2}\,dy \qquad (2)$$

in which the last term is the "probability integral", whose values are given in many mathematical tables; also

C = gain in carbon at a given point

C_o = *gain* in carbon at surface (surface carbon minus carbon content of original bar)

$y = (x' - x) \div 2\sqrt{Dt}$ (See note* below.)

The concentration curve may be plotted for this solution, plotting C/C_o in vertical ordinates computed for a series of values assigned to $x \div 2\sqrt{Dt}$ for the abscissa. Note that for this purpose the time t is given and the diffusion coefficient D is supposedly constant, and the curve may be plotted without assigning definite values for either t or D. Such a curve will properly define the concentration gradient for a diffusion coefficient which is independent of concentration, when a saturated concentration is always maintained at the surface throughout a given time t, and when the concentration remains at the original value at some very large distance from the surface. It is shown in Fig. 9 in dimensionless units, with numerical values of ordinates as far out as a value of 2.0 on the horizontal scale.

Now it should be apparent that the area under this curve is related to the amount of carbon added to the steel. If the theory is correct and the assumed simplifications not too erroneous, the curve should be fairly close to the concentration-depth curves derived from our carburization experiments, when the ordinates are

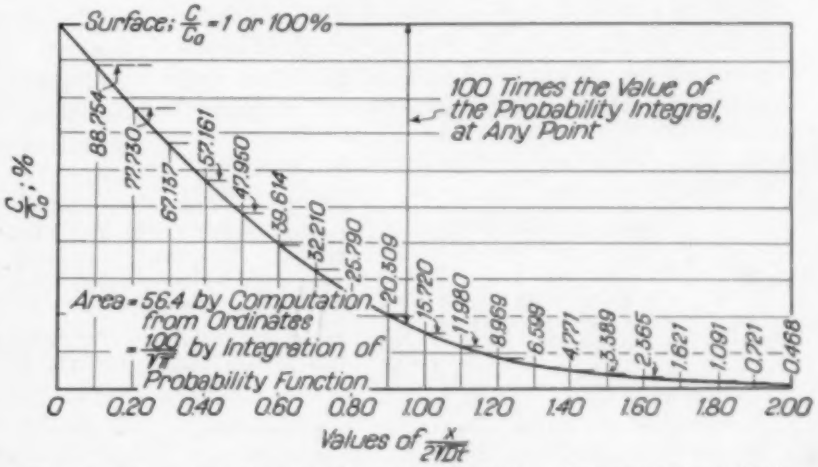


Fig. 9 — Concentration-Depth Curve Plotted in Dimensionless Units (Without Assigning Definite Numerical Values to Time or Diffusion Constant). It is the same as 1 — P.I. where P.I. is the "probability integral", values for which are taken from mathematical tables

per cent carbon, and abscissae are penetrations in inches (the data obtained from chemical analysis of depth cuts on the carburized bars). It is also obvious that the carbon actually added to the steel in any of our experiments is related to the area between the respective curve (Fig. 1 to 8, page 272A) and the horizontal line representing c_i or the base carbon of the original bar.† Likewise it may be possible for simplicity to replace the experimental curves by straight lines,

*Of significance only in the derivation of equation (2). A complete mathematical treatment of all solutions concerning diffusion rates and constants used in this paper may be found in "Diffusion in and Through Solids", by R. M. Barrer.

†Area under any of these curves (carbon added) may be measured by planimeter, or simply computed by assuming it to be a series of parallelograms, whose heights are the values of the ordinates as plotted and whose widths are the distance between ordinates. When the theoretical curve of Fig. 9 is so computed the total area out as far as $x \div 2\sqrt{Dt} = 2.0$ becomes 56.4, a close check to the theoretical value of $100 \div \sqrt{\pi}$, area under the probability curve to infinity.

which average the actual conditions fairly well. All these three lines should have this in common: That the area under the curves should be equal — that is, that they should represent the same *amount* of added carbon.

Three curves of this sort are plotted on Fig. 10, as follows: Curve 1 is the curve of Fig. 9, the gradient for a diffusion coefficient which is independent of concentration; curve 2 is a straight line which will define the "apparent case depth", assuming an average value for the diffusion constant and an average concentration gradient; and curve 3 the "standard concentration gradient", a composite compiled from the test-run analytical data as follows: Ordinate values of $100C/C_o$ are computed from the carbon analyses of the various cuts, and $x \div 2\sqrt{Dt}$ for the abscissa values computed from the mean depth of cuts for which the chemical analyses are taken.

These three gradients or curves will have one factor in common, namely, the area enclosed by all three will be identical. For the practical application in the carburizing process, this area will represent (when multiplied by some numerical factor) the added carbon accrued during that process. Since curve 1 is derived from Fick's law and is the same curve as Fig. 9, its area to the horizontal axis is $1 \div \sqrt{\pi}$ ($100 \div \sqrt{\pi}$, if ordinates are expressed in per cent), and the equivalent triangle *OSD* made by line 2 drawn from the ordinate $C/C_o = 100\%$ must cut the horizontal axis at a distance equal to $2 \div \sqrt{\pi}$ or 1.13. This point of intersection on the abscissa will be designated the "apparent case depth".

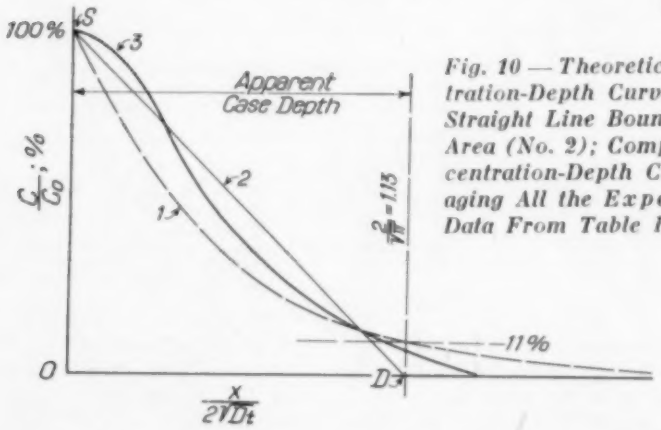


Fig. 10 — Theoretical Concentration-Depth Curve (No. 1); Straight Line Bounding Same Area (No. 2); Composite Concentration-Depth Curve Averaging All the Experimental Data From Table III (No. 3)

As will be shown later, the actual variation of the diffusion constant with concentration of carbon, neglected in Fig. 9, favors the assumption of a straight line gradient in the treatment given in Fig. 10, since the straight line No. 2 approaches the actual curve No. 3 much closer than the theoretical curve 1 computed on the assumption that *D* is independent of concentration.

Standard Carbon Concentration Gradient

It will now be necessary to explain in more detail how curve 3 of Fig. 10, the "standard" carbon concentration gradient, is derived. By definition it is an experimental curve, obtained from analyzing surface layers after normally carburizing steels of varying analyses and base carbons and at varying temperatures within the carburizing range. Analytical results are plotted with $100C/C_o$ as ordinates, with % of case depth for abscissas. The existence of such an average curve, closely approximating each of the actual test runs, is a logical deduction from the assumption that the *diffusion* rate of carbon in austenite is independent of the composition of the steel.* This deduction will now be tested.

On each of the curves in Fig. 1 to 8 a straight line is drawn from a point on the vertical axis to another point on the base carbon line (parallel to the depth axis) much as described above for Fig. 10. This line is so chosen that the area under it equals the area under the concentration-depth curve. The point of intersection with the initial carbon line is the "apparent case depth" as defined in Fig. 10.

The exact slope of this straight line is, of course, partly one of choice. In determining its slope, the experimental value of carbon in the first 0.005-in. cut is given little weight, due to loss of carbon while cooling the sample; the next three cuts are given equal consideration in determining the carbon gradient that must have been maintained during the carburizing period to produce the concentration found by analysis for these cuts. (The fact that a subsequent evaluation of the test data, using the surface concentrations chosen, led to a consistent curve in determining the "normal carbon gradi-

*Keep clearly in mind the distinction between diffusion rate and surface carbon. Diffusion rate can be relatively independent of alloy content, yet the estimated surface carbon evidently drops with an increase in nickel content. For example, take the figures for 1650° F.:

Steel	Nominal Nickel Content	Carbon at Surface
1020	none	1.24%
8720	0.55	1.22
3115	1.25	1.17
4320	1.80	1.19
4620	1.80	1.17
4820	3.50	1.11
2515	5.0	1.06

It is quite apparent that the surface carbon is also lowered by a decrease in the carburizing temperature.

ent" points to a reasonable consistency in determining these surface concentration values.)

Next the "apparent case depth" for each test piece determined as above was divided into ten equal parts and the dimensionless values for $100C/C_o$ were computed for each of these ordinates. A sample computation will be shown for steel NE8620 at carburizing temperature of 1650°, for 40% of apparent case depth: Since the apparent case depth as shown in Fig. 7 for this steel and temperature is 0.0587 in., conditions are to be figured at 40% of this depth or 0.02348 in., located at ordinate *R* in Fig. 7. Carbon content at this depth is given by point *T* on the 1650° curve which scales at 0.815%. Since the base carbon is 0.22, the carbon increase at the 40% mark, or *C*, is 0.815 — 0.22 = 0.595% (the distance *T-S*). Surface carbon for this run is probably close to 1.24% (point *P*) and the carbon increase at the surface, or C_o, is 1.24 — 0.22 = 1.02%. The dimensionless unit is therefore $C \div C_o$ = 0.595 ÷ 1.02 = 0.583 (or 58.3 if expressed in percentage). Similar values for the 1700° run and for the 1600° run figure out to be 59.0 and 57.5 respectively, a fairly good check between experimental values and the simplifying assumptions made about the diffusion constant.

Computations of this sort for all the curves for the eight steels fill a large sheet and average results are given in Table III.

When the values given in Table III above are plotted, as in Fig. 11, we have the "standard carbon concentration gradient" for normal carburizing. This curve, it will be noted, is developed from steels with varying surface carbon characteristics, at a range of temperature producing of itself a varied surface concentration for each steel. Table III simultaneously represents a wide range of added carbon and case depth values. With this wide range of surface carbon and case depth conditions, the averages and the standard deviations demonstrate a close agreement with each of the 24 test bars; necessarily each run checks nicely with the average. From this can be drawn two conclusions: 1. The condition of normal carburizing for each of the three runs is established. 2. The concept of one standard gradient, with dimensionless units, for the normal carburizing temperature range, and for a wide variation of steel specifications, is a fundamental one and can be used without error.

From this viewpoint a definition of case depth will now be attempted.

Table III — 100 C/C_o (Averages for All 24 Tests)

% Case Depth	Arithmetic Average	Standard Deviation *(a)*
10	90.3	1.3
20	81.4	1.0
30	70.7	1.5
40	59.1	1.0
50	47.2	1.2
60	35.8	1.0
70	25.6	0.9
80	17.2	1.3
90	11.0	1.3
100	6.7	1.4
110	4.0	1.4
120	1.9	1.1

(a) Three-quarters of the observed values may be expected to fall within this range, plus or minus.

Case Depth

The work of Wells and Mehl at Carnegie Institute of Technology, described in brief in a later paragraph, has shown conclusively that variations in grain size and, for the moderate amounts found in carburizing steels, additions of alloying elements have a negligible effect on diffusion rates.* It would also seem that a

*Of course these same factors may have a pronounced effect on *hardenability*, and since "case depth" is often judged from a fracture of a hardened bar, the hardened rim is mistaken for carbon penetration. For example, Earle C. Smith, chief metallurgist of Republic Steel Corp., pointed out in the discussion of Wells and Mehl's paper that there is no difference in carbon penetration in the commercial carburization of fine-grained nickel steels and

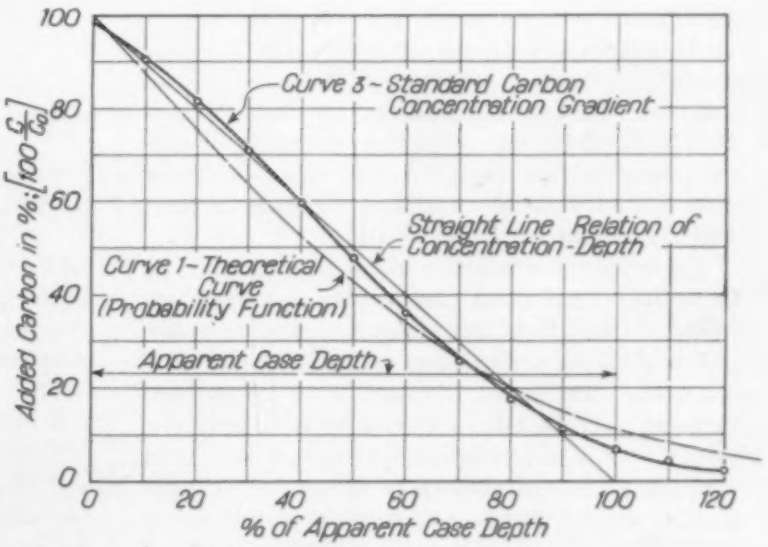


Fig. 11 — Experimental Results of Each of 24 Runs (Temperature 1600 to 1700° F., 8 Steels) Reduced to Dimensionless Units, Average Out Closely and Produce "Standard Carbon Concentration Gradient for Normal Carburizing"; Curve 3

specification based on the carbon gradient should be the proper one for defining case depth; the carburizing process is simply one of adding carbon, and by use of the standard gradient, concentrations at all depths may be readily predicted. For these reasons, it is suggested that case depth for a normal carburizing period be defined in terms of *(a)* amount of added carbon and *(b)* saturated carbon concentration. The convention of a straight line gradient has the merit of simplicity and of easy evaluation; when it is drawn to subtend the area corresponding to the true amount of carbon addition, and from the ordinate on the vertical axis representing saturated concentration, the point of intersection with the base carbon line is concisely defined. This intersection we have called the *case depth.*

This value can be calculated from a series of carbon analyses of successive layers, plotting the data, and measuring the area under the concentration-depth curve and above the base-carbon horizontal. The units will be % carbon added and inches depth. If this area is multiplied by four it will express the amount of carbon in pounds added to 10 sq.ft. of surface area (the surface area of 100 lb. of 1-in. round). If the figure for carbon added to 10 sq.ft. of surface area is divided by twice the gain in carbon at the surface, the result is the case depth.

As a specific example the area under the curve in Fig. 7 for NE8620 carburized at 1650° is 0.02995; the total carbon added to 10 sq.ft. of surface $= 4 \times 0.02995 = 0.1198$; the carbon increase at the surface, C_o, is 1.02% and the case depth is $0.1198 \div (2 \times 1.02) = 0.0587$ in. (This must, of course, check with the intersection of the average straight line for 1650° F. in Fig. 7, for this line was drawn to satisfy the requirements that the area under it is the same as the area under the experimental curve.) At the innermost limit of the case depth, so defined, the carbon concentration of the actual steel, as taken from this curve, is about 0.29%, 0.07% more than the base carbon.

Returning to all the data summarized by Table III, the derived case depths for the eight steels at the three temperatures may be computed. At each of the three carburizing temperatures, the case depth for each steel agrees well with the average for all steels. In fact, only one steel (S.A.E. 2515, with 5% Ni) shows a consistent variation in one direction; its values for C/C_o are slightly below the average, possibly due to lower surface carbons in equilibrium in this rather high alloy steel (see footnote, page 268).

A summary of the averages for the experimental data for all eight steels is as follows:

Temperature, °F.	1700	1650	1600
Absolute temp. *(T)*	2160	2110	2060
Total hours	8	8	8
Carburizing time *(t)*	7.5	7.5	7.5
Case depth for $t = 7.5$★	0.0684	0.0589	0.0483
Case depth for $t = 1.0$†	0.025	0.021	0.018

An empirical equation which fits these data giving the relationship between case depth *(C.D.)* in inches, time t in hours, and temperature T in absolute (Fahrenheit scale) is

$$C.D. = \frac{31.6\sqrt{t}}{(10)^{\frac{6200}{T}}} \qquad (3)$$

This expression can now be used in the evaluation of the theoretical curve 1 in Fig. 10. It will be recalled that it was plotted from an approximate solution of Fick's law; the area under it (proportional to the added carbon) is $1 \div \sqrt{\pi}$, and the intersection of the average straight line 2 with the horizontal is at $\frac{x}{2\sqrt{Dt}} = \frac{2}{\sqrt{\pi}}$.

Solving for D from this equation we have

$$D = \frac{\pi}{16}\frac{x^2}{t}$$

At $t = 1$ hr. and at $x =$ case depth we have

$$D = \frac{\pi}{16}(\text{case depth})^2 = \frac{\pi}{16}(C.D.)^2$$

and substituting the value of *C.D.* in equation (2), also for the condition of unit time, $t = 1$ hr., we have, for the average diffusion constant,

$$D_{(av)} = \frac{\pi}{16}\left(\frac{31.6}{10^{\frac{6200}{T}}}\right)^2 \text{ in in. per hr.} \qquad (4)$$

$$= \frac{\pi}{16}\left(\frac{31.6\,\frac{2.54}{60}}{10^{\frac{6200}{T}}}\right)^2 \text{ in cm. per sec.} \qquad (5)$$

$$= \frac{0.35}{(10)^{\frac{13400}{T}}} \text{ cm. per sec.} \qquad (6)$$

where equation (6) is had merely by substituting the value of π and reducing.

A general check can now be made on the validity of the assumptions in this work at Buick Motor's laboratories, by comparing the results computed by the above equation with the most satisfactory analysis of experimental data covering the diffusion of carbon in austenite, by Wells and Mehl in a paper entitled "Rate of Diffusion of Carbon in Austenite in Plain Carbon, in Nickel and in Manganese Steels", presented to the 1940 convention of the American Institute of Mining and Metallurgical Engineers. Wells and Mehl, in their experiments, butt welded 1-in. round rods

coarse-grained nickel steels in large production, but since the fine-grained steels are not so hardenable, the resulting thinner hardened "case" is often ascribed to a supposedly shallower penetration.

★Averages from Fig. 1 to 8, page 272A.

†Case depth for 7.5 hr. divided by $\sqrt{7.5}$.

of almost carbon-free Armco iron to hypereutectoid carbon steels, quick welding being done in a helium atmosphere and by electric resistance methods. These duplex bars were then heated in a surrounding inert atmosphere of argon, cooled quickly, and the movement of carbon across the weld line measured by chemical analysis of successive plates, machined off perpendicular to the axis.

Representative values for diffusion constant derived from these experiments are compared in Table IV with the average value of diffusion constant computed by our equation (6) on page 270.

Table IV — Comparison of Diffusion Constants

Temperature °F.	D_o by Wells & Mehl for 0.70% C	D_o by Wells & Mehl for 1.00% C	Buick $D_{(av)}$
1391	0.18×10^{-7}	....	0.22×10^{-7}
1697	1.6×10^{-7}	2.1×10^{-7}	2.19×10^{-7}
1841	3.7×10^{-7}	4.9×10^{-7}	5.22×10^{-7}
1841*	4.3×10^{-7}	5.6×10^{-7}	5.22×10^{-7}

*For steel containing 1.9% nickel.

General Table

Formula (2) for depth of case in inches is immediately available for computing the result of a run of any length at any temperature above Ac_3 in any medium that maintains a saturated carbon content at the surface. In Table V these computations are made for temperatures from 1350 to 1850° F. at 50° intervals, with times of 1 to 30 hr. The wide range of temperatures will be useful in estimating possible decarburization for various conditions of processing, as well as the effect of a diffusion period, when heating in a neutral atmosphere.

An example will now be given of the method of using Table V in determining the carburizing and diffusion cycle for a 0.20% carbon steel which will give 0.80% carbon at the surface and a case depth of 0.150 in. For a carburizing temperature of 1700° F. and assuming the concentration of carbon in the surface austenite to be 1.25%, the carbon increase at the surface, C_o, at the end of the carburizing cycle will be 1.25 — 0.20 = 1.05%. The eventual carbon at the surface after the diffusion cycle, however, is specified as 0.80%, an increase in carbon of 0.80 — 0.20 = 0.60%. The proportion between the two values, before and after the diffusion cycle, is 0.60 ÷ 1.05 = 57% (a figure for C/C_o). The carbon increase at the surface during carburization, plotted at *B* on Fig. 12, page 272, would be reduced to point *A* during diffusion. The final carburization gradient after diffusion may then be represented by the straight line *AD*, where *D* represents 100% of the eventual case depth (specified as 0.150 in.). The area under *AD* is the total added carbon.

Since the total added carbon must come into the steel during the carburizing cycle, the conditions at the end of the carburizing cycle are represented by the line *BC*, and since the area *BOC* must equal the area *AOD*, angle *OBC* equals angle *ODA*. *OC* represents the case depth at the end of carburizing, and is evidently

Table V — Case Depths in Inches for Various Times and Temperatures

Time in Hr.	Temperature, °F.										
	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850
1	0.006	0.008	0.010	0.012	0.015	0.018	0.021	0.025	0.029	0.034	0.040
2	0.009	0.011	0.014	0.017	0.021	0.025	0.030	0.035	0.041	0.048	0.056
3	0.011	0.014	0.017	0.021	0.025	0.031	0.037	0.043	0.051	0.059	0.069
4	0.013	0.016	0.020	0.024	0.029	0.035	0.042	0.050	0.059	0.069	0.079
5	0.015	0.018	0.022	0.027	0.033	0.040	0.047	0.056	0.066	0.077	0.089
6	0.015	0.019	0.024	0.030	0.036	0.043	0.052	0.061	0.072	0.084	0.097
7	0.017	0.021	0.026	0.032	0.039	0.047	0.056	0.066	0.078	0.091	0.105
8	0.018	0.022	0.028	0.034	0.041	0.050	0.060	0.071	0.083	0.097	0.112
9	0.019	0.024	0.029	0.036	0.044	0.053	0.063	0.075	0.088	0.103	0.119
10	0.020	0.025	0.031	0.038	0.046	0.056	0.067	0.079	0.093	0.108	0.126
11	0.021	0.026	0.033	0.040	0.048	0.059	0.070	0.083	0.097	0.113	0.132
12	0.022	0.027	0.034	0.042	0.051	0.061	0.073	0.087	0.102	0.119	0.138
13	0.023	0.028	0.035	0.043	0.053	0.064	0.076	0.090	0.106	0.123	0.143
14	0.023	0.029	0.037	0.045	0.055	0.066	0.079	0.094	0.110	0.128	0.149
15	0.024	0.031	0.039	0.047	0.057	0.068	0.082	0.097	0.114	0.133	0.154
16	0.025	0.032	0.039	0.048	0.059	0.071	0.084	0.100	0.117	0.137	0.159
17	0.026	0.033	0.040	0.050	0.060	0.073	0.087	0.103	0.121	0.141	0.164
18	0.027	0.033	0.042	0.051	0.062	0.075	0.090	0.106	0.125	0.145	0.169
19	0.027	0.034	0.043	0.053	0.064	0.077	0.092	0.109	0.128	0.149	0.173
20	0.028	0.035	0.044	0.054	0.066	0.079	0.094	0.112	0.131	0.153	0.178
21	0.029	0.036	0.045	0.055	0.067	0.081	0.097	0.114	0.134	0.157	0.182
22	0.029	0.037	0.046	0.056	0.069	0.083	0.099	0.117	0.138	0.161	0.186
23	0.030	0.038	0.047	0.058	0.070	0.085	0.101	0.120	0.141	0.164	0.190
24	0.031	0.039	0.048	0.059	0.072	0.086	0.103	0.122	0.144	0.168	0.195
25	0.031	0.039	0.049	0.060	0.073	0.088	0.106	0.125	0.147	0.171	0.199
26	0.032	0.040	0.050	0.061	0.075	0.090	0.108	0.127	0.150	0.175	0.203
27	0.033	0.041	0.051	0.063	0.076	0.092	0.110	0.130	0.153	0.178	0.206
28	0.033	0.042	0.052	0.064	0.078	0.094	0.112	0.132	0.155	0.181	0.210
29	0.034	0.042	0.053	0.065	0.079	0.095	0.114	0.134	0.158	0.185	0.214
30	0.034	0.043	0.054	0.066	0.080	0.097	0.116	0.137	0.161	0.188	0.217

57% of *OD* or 57% of 0.150 in., that is 0.086 in.

The carburizing time, then, is one that will produce a depth of 0.086 in. at 1700° F., and this is found in Table V as 12 hr. Diffusion time, also at 1700° F., is computed from the principle that case depth varies as the square root of time in hours, as shown by the % time figures along the horizontal axis of Fig. 12. Carburizing time on this run (12 hr.) will be about 33% of the total; subsequent diffusion will be 67% or 24 hr.

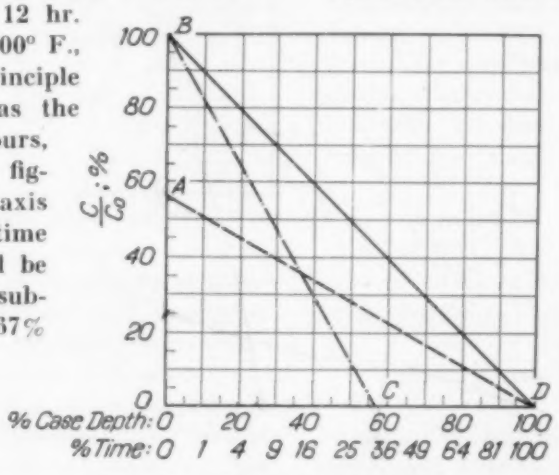


Fig. 12 — Carburizing-Diffusing Cycle for 100 C/C. = 57

A check on the total time, carburizing cycle plus diffusion cycle, is $(0.150 \div 0.025)^2 = 36$ hr., since *C.D.* for 1 hr. is 0.025, and *C.D.* varies as the square root of time — see equation (3).

The general principles expounded here may be extended to other conditions, such as a diffusion cycle in a neutral atmosphere at a higher or lower temperature than the carburizing temperature.

Likewise the reverse of the carburizing mechanism occurs during a heating which decarburizes steel. In that event it is necessary first to know the carbon content in the steel that is in equilibrium with the furnace atmosphere at the given temperature. Values of Table V would then be applicable to decarburizing depths on steels of uniform carbon concentration.

Conclusion

The purpose of this rather lengthy article should not be regarded as to establish saturated austenite values, or to derive concise diffusion constants; rather it proposes, from a commercial carburizing test, to establish a standard for the control and evaluation of carburizing procedures. The attainment of normal carburizing conditions is not difficult, and the evaluation of such operations need not be discussed here. Table V and Fig. 12, covering carburizing-diffusion cycles of carbon in steel, are included to demonstrate the applicability of the case depth and carbon gradient derivations to practical carburizing problems and cycles.

BITS AND PIECES

METALLURGICUS' OWN DEPARTMENT

(An ♁ book of your choice for a publishable item)

Hardness Tests

HERE are a few remarks on the mechanical aspects of hardness testing which may be of alue today to the newcomer, or the old hand ho is forgetful:

I. **Brinell Testing.** Since the hardness num- r in a true Brinell test (BHN) is found by easuring the diameter of the ball impression *ter removing the load,* the quality of the support s very little if any effect on the BHN *if* the ball free to follow up the test piece as required. hat is, the piece may yield or deflect, it may st on rubber or a spring, and the result will be e same if the full load can be applied. Most rinell machines are operated by a direct-acting draulic press and have a fairly large travel of e ball, so the ball will follow the work, and if e load is actually applied to the ball, the impres- on gives a good BHN.

II. **The Direct-Reading "Brinell" machine** epends usually on a depth gage, the number presenting the hardness being read off the dial *hile the load is on.* Therefore, the piece must ot deflect; if so the deflection will influence the ial reading. Firm support *directly under the st spot* is required. However, most machines f this type divide the total load of 3000 kg. into o parts, a pre-load or "seating" load, and then e load which actuates the dial; the pre-load ill usually break down scale or dirt between the upport and the test piece.

Note that, since the total load is usually 000 kg., the impression diameter can later be ead under a glass to give a true BHN.

III. **Rockwell.** Here the hardness number is btained from a depth-gage dial, but *after* remov- g the load. The pre-load, however, is only 10 kg., so there is not much force to seat the test piece firmly on the support block; hence clean metal-to-metal contact must be provided. But, since the dial is read after removing the load, a considerable elastic motion of the work is tolerable. That is, we may test satisfactorily on bridge supports — and indeed this is often the best way of holding irregular work for Rockwell testing. This kind of support would not be satisfactory for direct-reading "Brinell" testing.

IV. **Carbide Balls.** It might be in order to remind our public of the usefulness of tungsten carbide balls, rather than steel balls, when the hardness range is above, say, 500 BHN. Carbide balls will last much longer, being harder; having a higher modulus of elasticity, they give slightly smaller impressions at high hardnesses than steel balls, but correlation is easy — see the *Metal Progress* data sheet showing the work of Scott and Gray (October 1941, page 524). Carbide balls are especially worthy of consideration today when imported Brinell balls cannot be had.

By using a carbide ball on a Brinell or direct-reading "Brinell" type of tester, hardness tests may be made faster and with less surface preparation than by Rockwell testing in the range up to Rockwell C-60.

METALLURGICUS

Quick Action Quench Jet for Jominy Test

IN CONSTRUCTING a pair of Jominy end-quench test-rigs for Australian firms the main difficulty was in connection with the height of the unimpeded water jet, since the use of a pump and valve tended to build up pressure to give a higher column of water at the commencement of the test. A constant level water supply tank

seemed simpler. Later, instead of a quick opening valve, a disk 1½ in. in diameter was substituted for the valve. Prior to operations the water jet is adjusted to the correct height and the disk, on a pivot arm, swung in a horizontal plane midway between the end of the pipe and specimen's position over the jet. When the heated specimen is inserted in the holder the disk is swung out of the way for the duration of the test. Quick action is had by attaching a spiral spring to the side of the disk and latching the latter in place to impede the jet. Tripping the latch then allows the spring to jerk the disk to one side, and quenching starts.

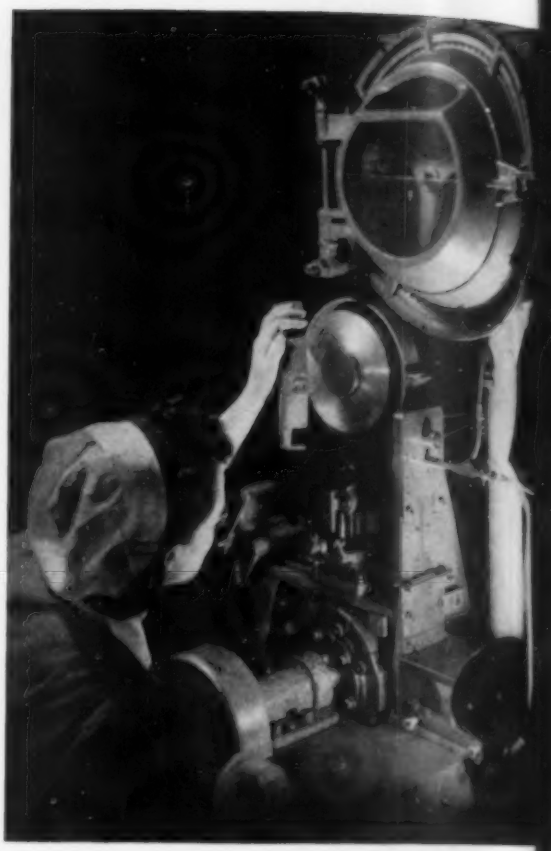
Over a series of tests the water may continue to flow undisturbed, spraying either the test specimen or the disk. (JACK R. ALLSOP, Instructor in Metallurgy, School of Mines and Industries, Ballarat, Victoria.)

Makes Disks, Seats and Inspects Automatically

A MACHINE that does the work of approximately 75 persons has been developed by engineers of Aluminum Seal Co., New Kensington, Pa., for use in government arsenals. Called a "foil disk assembly machine", the unit is employed on loading lines for seating foil disks in detonator cups. Previously, disk seating was a laborious hand operation. The tiny foil disks, which measure less than 0.25 in. in diameter, were gaged by a micrometer to insure that only one disk went into a cup, placed by tweezers in the cups, and seated with a small hand press.

In the new machine the detonator cups are placed in the hopper shown at the top of the photograph, from where they pass automatically, right side up, into a feed chute to a punch which transfers the cups, five at a time, into a seating block on an intermittent turret wheel. The turret carries the cups past a die which blanks out the foil disks and pushes them to the bottom of the cups. The foil is coated on one side with a thermo-plastic adhesive, and is fed automatically past the punch and die. A vacuum shoe holds the disks to the seating block, and permits the punch to return to its original position without carrying the disk along with it. Further revolution of the turret takes the detonators to a station where a little heat seals the disks into the bottom.

After seating, the detonator cups pass to the next station where they are released and drop into an automatic inspection unit. At this point the cups are pulled out of the inspection turret by



Operator Examines Foil Container in Foil Disk Assembly and Inspection Machine

vacuum, to drop into a bin below. In the ev that the disks are not properly seated the cu are not ejected by the vacuum plunger but a carried around in the turret to a reject box.

Besides materially speeding the operati the new machine eliminates one of its ch hazards. Sealing by thermo-plastic insures pe fect adherence and prevents the powder fr seeping underneath the disk. A marked decre is noted in the number of cups rejected for th reason. (W. S. MCARDLE, Publicity Bureau, Al minum Co. of America.)

Pre-Treatment of Copper-Lead Bearings

IT IS DESIRABLE to have a thin layer or sk of lead on the bearing surfaces of copper-le bushes, to facilitate ease of "running in". Th lead acts as a lubricant in the first running of th engine, and during the bedding-down of th crankshaft. This layer of lead is usually obtaine by dissolving away the copper at the surface o the bearing, leaving the lead standing proud The most common reagents employed for thi

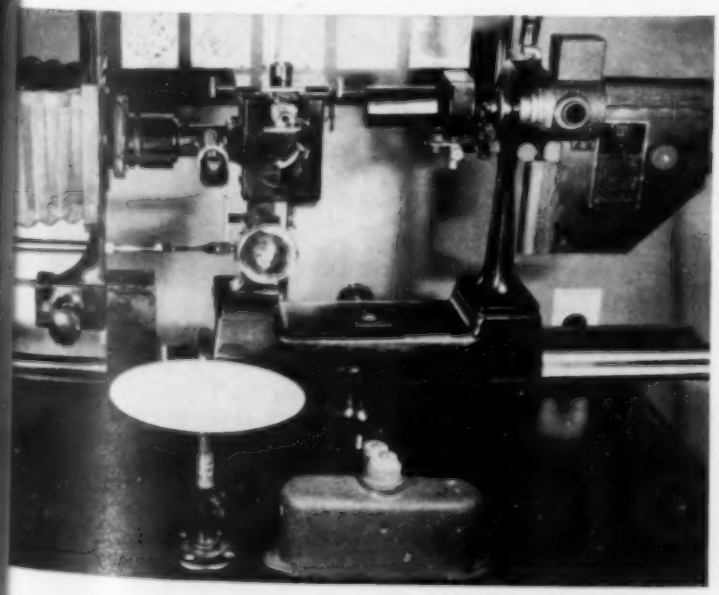
ocess are chromic or sulphuric acids, which ve decided disadvantages in use. For example, y are messy to work with, the etching nor- lly having to be carried out hot; the acids ack the steel backing of the shell; and hydro- n is evolved during the process.

These disadvantages can be overcome, how- er, by use of an alkaline solution composed of % trichloracetic acid, 20% water and 60% con- ntrated ammonia. This alkaline bath is used ld and can dissolve 0.001 in. of copper from rface of a copper-lead bush in 6 to 7 min.

The lead is only very slightly attacked by the lution, and after immersion the surface of the sh has a light gray matte appearance. The eel shell is not etched, the surface finish is aintained, and pitting is avoided. (C. W. ILKINS, Metallurgist, Albion Motors, Ltd., Glas- w, Scotland.)

Observation Disk for Microscopic Examinations

ROUTINE microscopic examinations of diversi- fied nature are greatly facilitated by adapting he metallosCope so it projects the image upon a onveniently located observation disk. Details of onstruction and assembly are simple, as is evi- ent from the accompanying photograph. A right ngle prism is fitted over the conventional onocular eyepiece, and directs the image to an djustable horizontal disk of white enameled teel. The prism attachment may be shop con- tructed or purchased from an optical company. The disk assembly was constructed from odds and ends found about the work shop; two tele- scopic tubes support the disk and provide for vertical adjustment. This adjustment, in con- junction with the proper combination of objective and ocular, provides a wide range of magnifica- tions. For best results the metalloscope should be equipped with electric arc and prism-type vertical illuminator, and in a darkened room.



With the arrangement described, as many as 1200 consecutive measurements of decarburiza- tion or grain size are being made daily without eyestrain or other discomforts which generally accompany prolonged observations made in the conventional manner. (C. D. FOULKE, Research Metallurgist, Weirton Steel Co.)

Quick Test for Manganese in Steel

A TEST which we have found handy in spotting toolsteels (one with manganese about 1.50 and another about 0.30%) is based on the same reactions as the tests recommended in May *Metal Progress*, page 746, but with different procedure. It is based on the oxidation of manganese in the steel to the permanganate ion with its character- istic purple color; the oxidizing agent is ammo- nium persulphate with a small amount of a silver salt as a catalyst. The larger the amount of manganese in the steel, the deeper is the purple color of the resulting solution. A set of color standards for various manganese contents can be made up from dilute potassium permanganate.

The test is conducted as follows:

1. A small piece of filter paper is placed on the clean steel surface and three drops of 1-to-1 nitric acid are dropped on it. After reaction ceases the filter paper is rolled onto a glass stirring rod and transferred to a pyrex test tube.

2. Five ml. distilled water are placed in the test tube, with a few drops of concentrated sulphuric acid.

3. The solution is brought to a boil, five drops of silver nitrate solu- tion (8 g. $AgNO_3$ per l.) are then added, and the solution is again heated to boiling.

4. Ten drops of ammonium per- sulphate solution (30 g. per 100 l.) are now added to the test tube and the solution brought to a boil for about 30 sec., until the purple color develops. (R. G. TOWNSEND, Chief Chemist, Metallurgical Department, Jones & Lamson Machine Co.)

Due to the fact that, up to very recent years, production of aluminum ingot, its alloying and rolling was in the hands of a single producer, details of these operations and equipment for them have not been publicized. The following article, therefore, is believed to be unique and first entrance into an importa field, whose interest will doubtedly widen in the futur

MELTING, ALLOYING, HEATING ALUMINUM AND ALLOY INGOT

By R. R. LaPELLE

Manager, Special Furnace Division, Dempsey Industrial Furnace Cor

THE PURPOSE of this paper is to describe in a very brief way the equipment and methods used in melting, alloying, casting and heating the high strength aluminum alloys. Many variations of the methods outlined are practiced for specific purposes, but in general the methods used are those discussed herein. It is hoped that this article will serve as an aid to anyone who is not familiar with the art, and who is called upon to carry out these processes.

Melting

Aluminum metal is produced in the primary production plants from bauxite ore which has first been converted to alumina (Al_2O_3) by chemical treatment. The highly purified alumina is then fed into a bath of molten flux in an electrolytic cell at a temperature well above the melting point of aluminum. The aluminum metal liberated by electrolysis is ladled out and cast into pigs of virgin aluminum which form the raw material for the foundry or cast house.

In some cases the material received by the user — particularly the foundryman — has already had the necessary alloying elements added to it, in which case the problem requires only remelting and casting into the desired molds. Such metal is then usually remelted in small pots, frequently of the tilting or nose-pouring type. These furnaces consist of a steel shell, a refractory lining, a means of supplying heat (usually gas or oil burners) and a cast iron pot or container for the charge.

After the metal has been melted, it is fluxed either by bubbling chlorine gas through the bath or by using a powdered flux which is inserted below the surface of the liquid. If grain-refiners such as calcium are to be used they are also added to the molten charge at this time.

Melted metal is then poured into small hand ladles and thence into the molds, in the case of sand castings, or into the special holding pots of die casting machines or pressure casting machines. Any scrap resulting from the melting operations may be remelted in the pot type or crucible furnaces where the volume remelted is small. In large operations the scrap is usually remelted in a reverberatory furnace as described hereafter.

Reverberatory Furnace Design

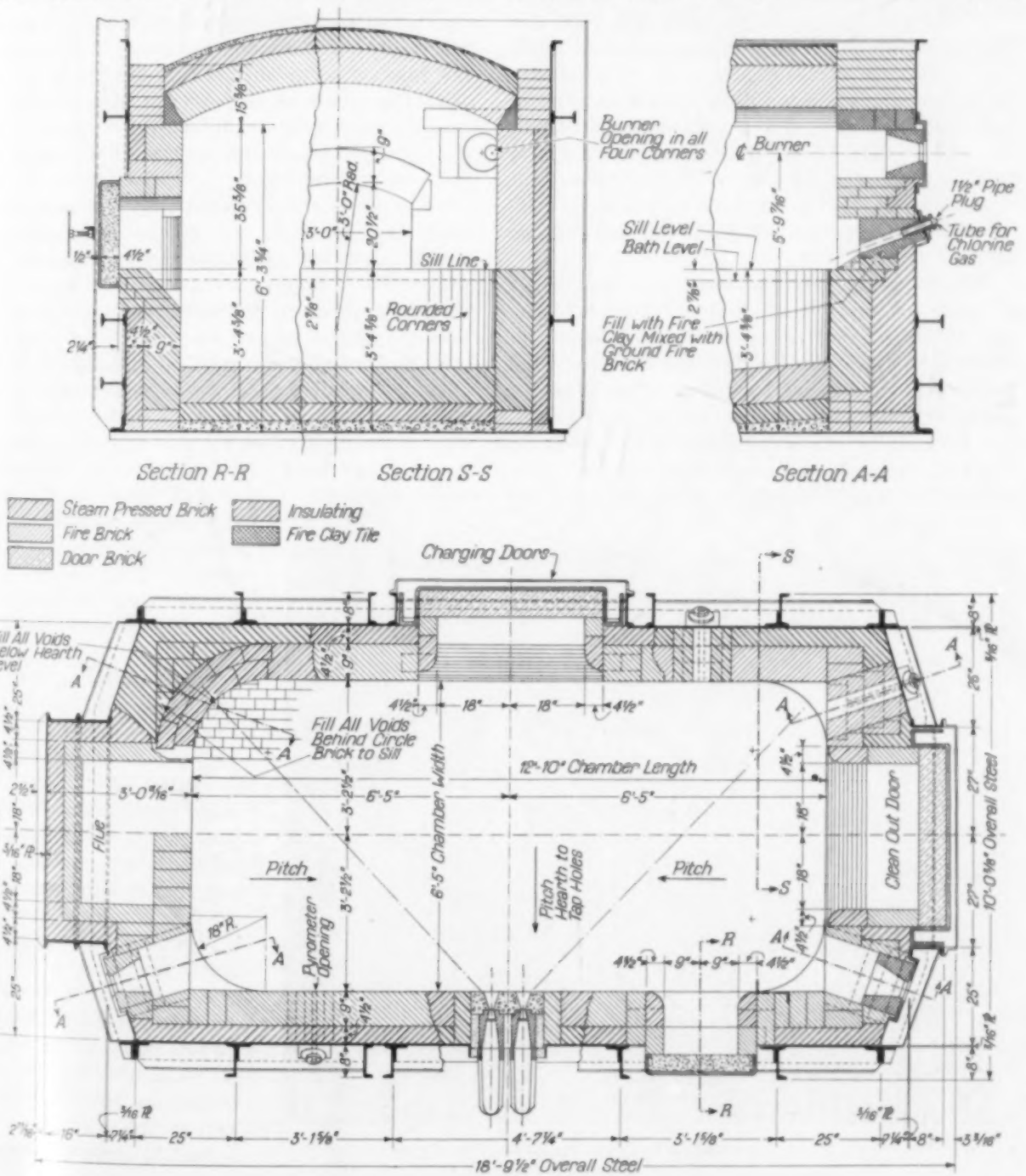
Reverberatory furnaces consist essentially of a structural steel housing lined with refractory brick, and heated by oil or gas burners firing above the bath level, or coke in a fire box located at one end of the chamber behind a bridge wall. Figure 1 is a general drawing of an oil-fired reverberatory aluminum melting furnace, and Fig. 2 (page 278) shows a coke-fired furnace.

In these furnaces melting takes place directly

on the brick hearth and a considerable quantity of molten metal can be obtained at one time. Standard size furnaces of this character hold 10,000, 20,000, 25,000 or 35,000 lb. of metal.

Where the metal comes to the furnace already alloyed, or where continuous casting seems desirable, it is convenient to arrange for continuous operation. This is accomplished by dividing the furnace hearth into two separate chambers by a refractory wall, each controlled by its own burners. The metal is melted down in one end, known as the "melting chamber", and the major part of the dross removed. The purified metal is then transferred to the other end, known as the "refining chamber", fluxed and finally purified. Metal may be cast from the refining chamber while a second charge is being melted down in the melting chamber. If desired, alloying may be done in the melting chamber and the alloyed metal then transferred to the refining chamber for final purification. Metal may be transferred by ladle, or directly by a syphon.

Fig. 1 — General Plan and Sections of Oil-Fired Reverberatory Furnace for Melting Aluminum Pig and Alloys



Fuels

One of the evils to which molten aluminum is subject is the absorption of hydrogen. Hydrogen causes voids, blowholes and generally porous castings. This is the necessity for chlorination and fluxing, since both of these methods contribute to the removal of absorbed hydrogen.

This tendency of aluminum to absorb hydrogen is influenced to some extent by the amount of hydrogen or water vapor in the furnace atmosphere. Those fuels whose products of combustion contain the least hydrogen, either molecular or combined, are therefore preferred. Of the fuels available, dry coke in dry air produces practically hydrogen-free products of combustion. Oil burns to gases containing considerably more hydrogen, and gas, either natural or artificial, burns to products of combustion having the greatest amount of hydrogen. For metallurgical reasons alone, therefore, coke is generally preferred, with oil as second choice and natural gas as third choice.

Unfortunately the choice of fuels can seldom be made on purely metallurgical grounds. The use of coke involves considerable expense in storing, handling and drying the fuel, in firing the furnaces and in ash handling. These expenses are absent with either gas or oil fuel.

An equally important objection to coke is the fact that the melting time is much longer. This means that if coke is selected as a fuel, the furnaces must be either of a larger holding capacity or more of them must be built.

A consideration of all of these features, plus the local factors of availability and cost of the various fuels, leads to different solutions in different places. Most aluminum melting furnaces currently being installed in the United States are fired with fuel oil. This is the most workable compromise; however, entirely satisfactory work is being obtained from all three types of firing.

Alloying and Cleaning the Bath

When melting virgin aluminum, it is necessary to add the alloying elements, if any, within the furnace. For this reason the reverberatory should be made as large as possible, having due consideration to the total output required from the plant as a whole and the type of casting equipment being employed. The reason for this is, of course, that the operations of alloying and analyzing the bath are practically identical regardless of the size of the charge, and since the procedure is somewhat laborious it is desirable to secure as much properly controlled metal as possible with each batch handled.

The procedure in melting under these conditions is to charge the furnace with virgin aluminum pig, plus such scrap as may be available, to approximately half its nominal capacity. As soon as this has been melted down, the remaining metal is charged and melted down, and the bath skimmed to remove dirt and oxide carried in by the metal melted. (Figure 3 shows the flux being removed from the cleaning door into a special flux buggy.)

All materials entering the melt must be of known analysis and carefully weighed in order that the necessary alloying additions may be calculated. An addition, if in lump form, is fastened to a rabbling rod and stirred into the bath in much the manner in which a lump of sugar on a teaspoon is stirred into a cup of coffee. Smaller pieces are easily handled in baskets of perforated iron. Magnesium pig, which is lighter than aluminum, must be held below the surface until melted, to prevent oxidation.

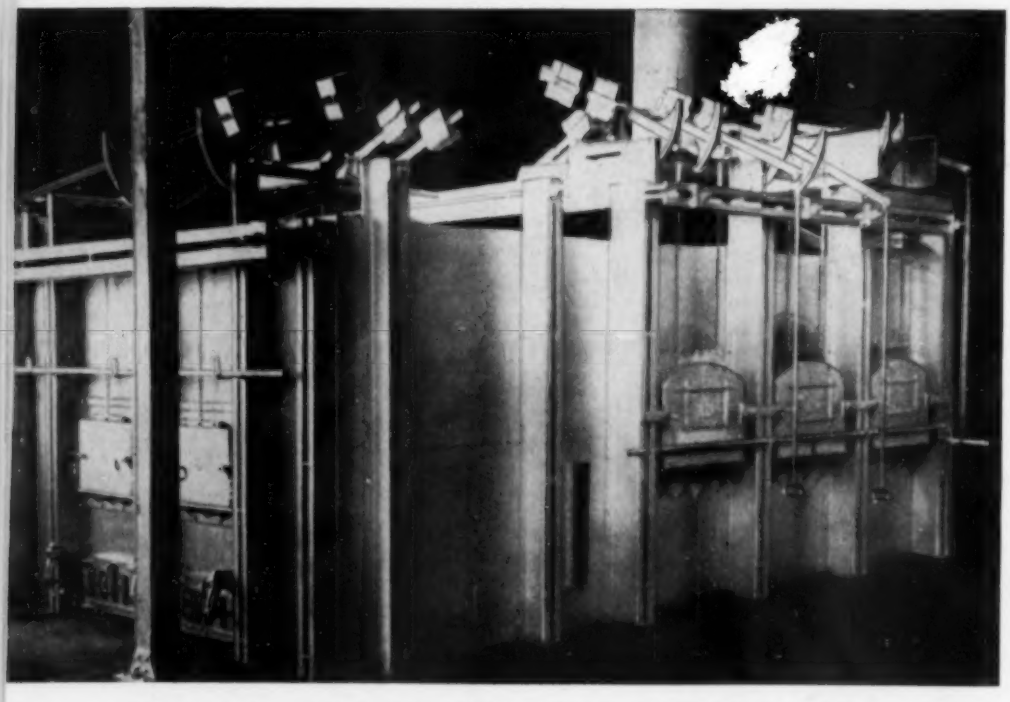


Fig. 2 — View of Coke-Fired Melting Furnace From Fire Box End

Alloying elements are generally added in the form of "hardeners" — alloys of aluminum and the metal being added — commonly of the following compositions:

Hardening Element	Composition
Copper	20% copper-aluminum
Manganese	5% manganese-aluminum
Silicon	12% silicon-aluminum
Nickel	10% nickel-aluminum
Magnesium	Added as virgin pig

When all of the hardening elements have been dissolved, the metal is rabbled thoroughly to insure uniform dispersion to all parts of the bath. This rabbling process may take from 15 to 30 min., or even more, but must be thoroughly done. A sample is then withdrawn from the bath by a small hand spoon, cast in a metal mold into the pieces required for spectrographic and chemical analysis.

Analysis generally requires from 20 to 40 min., and the bath must be held at fluxing temperature until the laboratory report is received. If ready to go ahead, metal is thoroughly fluxed by either chlorine or chloride flux. The procedure, when using chlorine gas as a de-hydrogenizer, is to insert pipes connected to cylinders of chlorine, through the doorways or special chlorine openings so that the ends of the pipes are below the bath level. The pipes are then moved about throughout the molten metal while chlorine is bubbled slowly through. From 15 to 30 min. is frequently required for this action.

Where powdered chloride flux is used, this is usually inclosed in aluminum tubes which are inserted below the bath level by means of a special end tool, as shown in Fig. 4. The hot metal promptly dissolves the aluminum tubes liberating the chloride powder below the surface of the liquid. Decomposition of the flux results in a violent agitation of the bath and removes the dissolved hydrogen. Obviously, where flux is used, sufficient must be provided to reach all parts of the bath in order thoroughly to purify the metal.

Fluxing by either method should be carried on at temperatures in the neighborhood of 1275° following which the metal must be raised to the pouring temperature, generally 1325 to 1350° F., as rapidly as possible and the metal poured immediately after final skimming.

Casting Technique

Where the metal is to be cast, prior to movement to some other department for remelting in pots, or for shipment outside the plant, it is customary to use a mechanized casting device known as a mold conveyor. This consists essentially of traveling chains to which are fastened a series of cast iron molds of desired size and shape. The conveyor is arranged to pass below the pouring spout, up a slope, and over a head shaft to dump the metal into a tote box or other receiver. Sufficient distance must be allowed between the casting point and the head shaft for the metal to freeze and partially cool, so it can be removed readily from the molds. Figure 5, page 281, shows the operation of casting with a conveyor type of machine.

Such casting is almost automatic. The metal stream from the furnace is controlled by an adjustable plug which fits into the pouring sleeve; it is fitted with a hand lever to control the rate of flow. External gas burners are often used to keep the spout open. After leaving the furnaces the

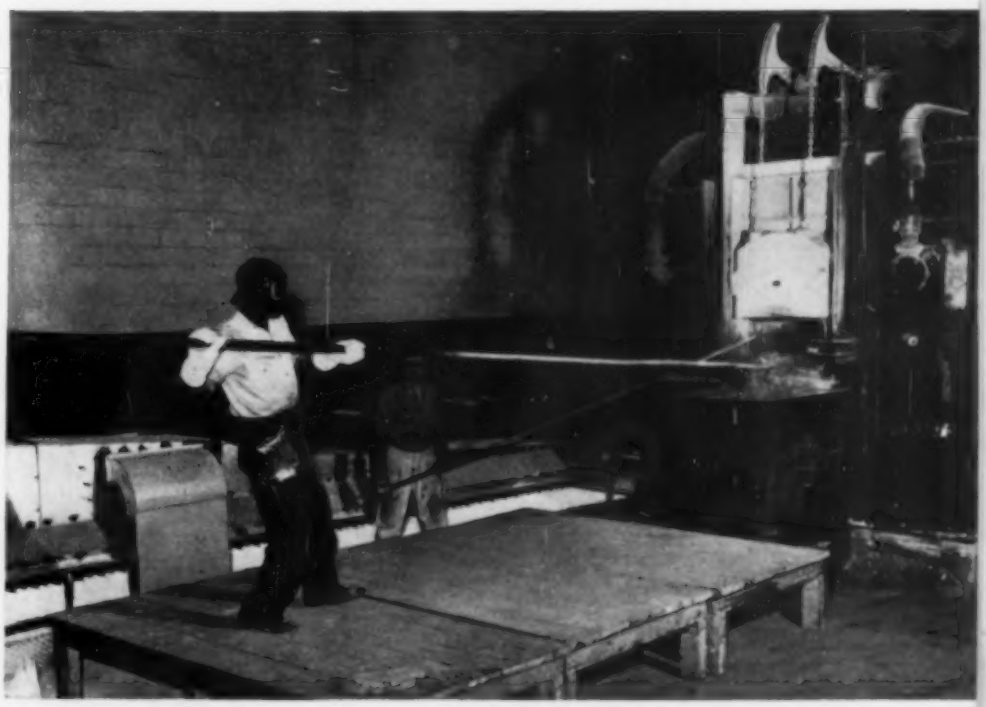


Fig. 3 — Pulling Flux From Melted Charge Through Clean-Out Door Into Small Buggy. This furnace is built from plans like Fig. 1; note steel sheathing, burners, and opening for chlorine pipe below burner. Cooling hood is for conveyor along wall

metal flows into a small basin which acts as a receiver; it is tilted to pour into each mold as it passes beneath. When each mold is full the operator simply raises the nose of the basin slightly thus stopping the flow until the next empty mold comes by. The conveyor moves continuously and the operator fills the molds one by one as they pass beneath.

Book Molds — Small ingots, as well as some fairly large ones, are frequently cast in "book molds". These are of cast iron, water jacketed, and hinged on one side so they may be opened like a book to discharge the finished ingot.

A group of such molds is generally mounted on a rotating circular table (or in a stationary arc). In the rotary table, or merry-go-round, each mold is brought below a runner leading from the pouring spout of the furnace and slowly filled with metal. Otherwise, the runner itself is moved to pour into any one of the molds. The runner is generally lined with refractory material, and in most cases externally heated by ribbon type of gas burners.

When casting ingots in book molds, a further refinement is usually introduced, which tilts the molds 45° from the horizontal at the start. (This prevents splashing of the metal which, if permitted, would result in frozen droplets of metal imbedded in the sides of the ingot, causing imperfections.) As the mold fills it is slowly returned to the vertical position until it is seated upright at the end of the casting period. After the mold has been filled, the continued solidification of the metal creates shrinkage in the center of the mass which would result in a piped ingot. To prevent piping, metal is added to the mold by a hand ladle until freezing is completed. This requires the use of a small holding furnace to provide molten metal, and the constant presence of a skilled workman.

Direct Casting — For the manufacture of many small ingots and for almost all large ingots a "direct casting" process is usually employed, using a hydraulically operated platform containing one or more "heads". These heads, in the raised position, meet the bottom of stationary water cooled molds or sleeves. It is usual to place sheets of aluminum foil, fitting the heads firmly against the stationary molds at the start of the process. Molten aluminum is then run from the furnace to a distributing head just above the stationary molds. From the distributing head it passes through adjustable orifices into the stationary molds where it immediately begins to freeze. After freezing begins the hydraulic equipment is set in motion, slowly moving the casting heads downward away from the stationary molds. The speed of travel must be carefully adjusted to coincide exactly with the speed of freezing and the rate molten metal is added to the stationary mold. With the device just described, ingots having lengths of 10 ft. or more may be readily cast in one piece. When the head has reached its extreme position, the flow of molten metal is of course stopped, the last portion of metal to reach the stationary mold solidifies, and the finished ingot removed preparatory to starting the next cycle. Obviously this is a semi-continuous method of casting.

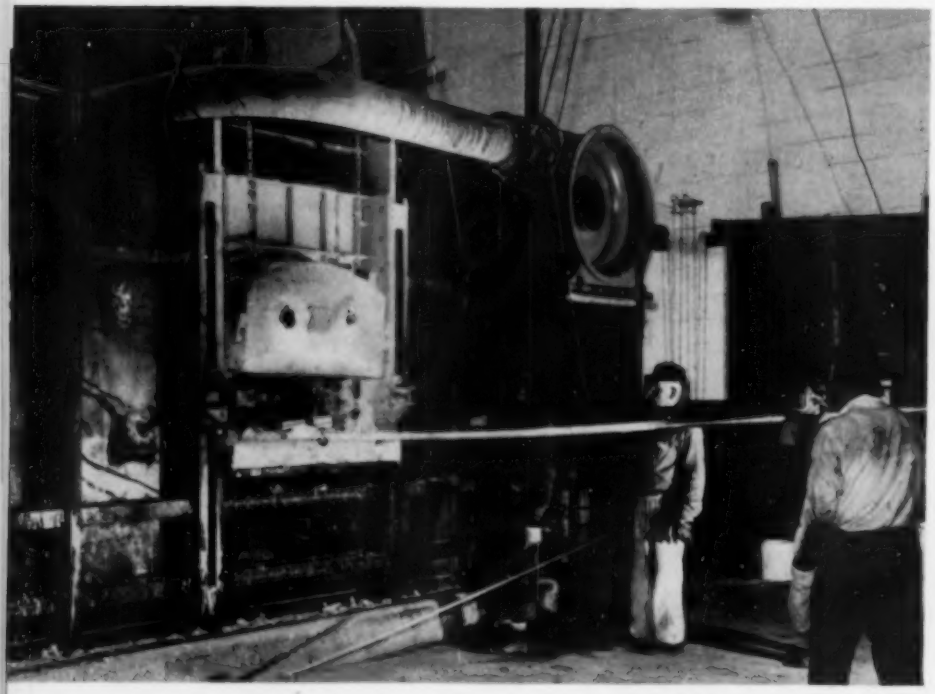


Fig. 4 — Introducing a Bundle of Aluminum Tubes Containing Powdered Chloride Flux Into the Bath

Continuous Casting methods, developed by the Rossi Engineering Co., are now in use for the casting of aluminum ingots. Operations are somewhat similar to the direct casting of copper wire bars, wherein molten metal is held at carefully controlled temperature in a pot that has a water cooled spout in its bottom, and through which a frozen bar of metal moves downward at a continuous slow rate, to be cut into lengths periodically by a cut-off saw. This process is thor-

loughly continuous instead of intermittent, as in the case of the direct casting process.

Operating Precautions

In order to secure a good life from any metal parts in contact with molten aluminum, they should preferably be made of cast iron. They should further be covered with a tight and uniform coat of French chalk, or hydrated lime. This wash must be renewed at frequent intervals.

A similar coating, if applied to the furnace brickwork, will greatly increase its life. This is true largely because the chalk prevents aluminum or its oxides from adhering to the brickwork and hence greatly simplifies cleaning the furnace. The coating will be lost when the furnace is cleaned (which should be done not less often than once a week). A spray gun attached to a long pipe will be quite satisfactory to re-apply the whitewash.

Homogenizing the Ingots

In the freezing of the strong aluminum alloys the various constituents solidify at slightly different temperatures. As a result of this, the alloy elements tend to segregate in various manners. If such a badly segregated ingot is hot worked by rolling, forging or extrusion, fracture is almost certain to result. Likewise, if machining or cold work is attempted, the metal is very apt to tear or work unevenly.

The bad effects of this segregation can be largely eliminated if the metal is given a heat treatment known as homogenizing or normalizing, consisting of heating it to a temperature just under the melting point of the lowest melting constituent and holding it there for 6 to 10 hr., depending on the ingot size and analysis. Cooling may be done in any convenient way, since ingots are usually reheated for hot work after homogenizing. If desired, however, the temperature may be dropped immediately after the soaking cycle to the rolling or forging temperature, generally 100° or so lower, and hot worked immediately after the ingot has reached this temperature throughout.

Homogenizing is generally carried out in electric, gas, or oil-fired recirculating furnaces. Temperature uniformity is quite important, and a large volume of recirculated air produces the best possible conditions. Control of atmosphere's composition is not especially important, since most ingots to be rolled or forged will be scalped following homogenizing, and ordinary hot air does not cause any deep-seated oxidation. (Billets which are to be extruded generally do not even require scalping.) Figure 6, page 282, shows a recirculating furnace, suitable for homogenizing.

Homogenizing temperatures in the metal itself range from 925 to 960° F. for various analyses in common use. Cycles depend, of course, on the size billet being handled, but range from 12 to 22 hr. for the usual sizes used for forging and rolling purposes.

In spite of all that can be accomplished through homogenizing treatments, a certain amount of extreme segregation still exists near the surfaces of large aluminum alloy ingots. This "skin effect" must be eliminated before acceptable sheet or bar can be produced, suitable for aircraft work. This can be done by milling or planing the surfaces, known as "scalping". It is important to scalp *after*, instead of before, the homogenizing treatment, as otherwise defects are developed in the ingot surface which persist throughout the rolling or forging operations.

Fig. 5 — Casting Pigs in a Continuous Chain of Molds

Scalping can be done in any suitable planer or large milling machine. However, special automatic machines are usually installed to reduce the labor to a minimum, and speed the operation.

Preheating; Cladding; Annealing

After scalping the ingots are heated for rolling, forging or extruding in a recirculating type of preheating furnace, usually of the continuous conveyor type, fired with gas, oil or electricity. Temperature uniformity is important, as the working range is narrow; the metal is both hot-short and cold-short. In other words, the working range is only about 80° F. on the usual alloys. Naturally, it is desirable to begin working at the extreme upper end of this range, in order to do the maximum amount of work; at the same time, the safe temperature must never be exceeded, as this would ruin the piece.

Aluminum alloys which are to be used in thin sections, such as aircraft sheets, are usually given a coating of pure aluminum to prevent corrosion. Such composite material is called "Alclad" and "Pureclad" by the two principal American manufacturers.

Cladding is applied after the initial breakdown rolling and scarfing. A sheet of pure aluminum, usually about ¼ in. thick, is placed on each surface of the slab and bound in place by steel strapping; this "sandwich" goes through the reheating furnace, and then to the rolling mill.

Just before the slab enters the rolls, the steel straps are removed, and the sandwich rolled as one unit. Under the heavy pressure, the pure aluminum welds to the aluminum alloy slab, and further reduction is carried out in the usual way. The sheet finally resulting will have a pure aluminum coating, very tightly bound over the entire area, of the same *relative* thickness as the sheet bore to the original alloy slab.

After hot working has been carried to its economic limits, it may be desirable to further reduce the aluminum bar, rod or sheet, by cold working. This is done in conventional rolling mills or draw benches, as may be indicated by the product desired.

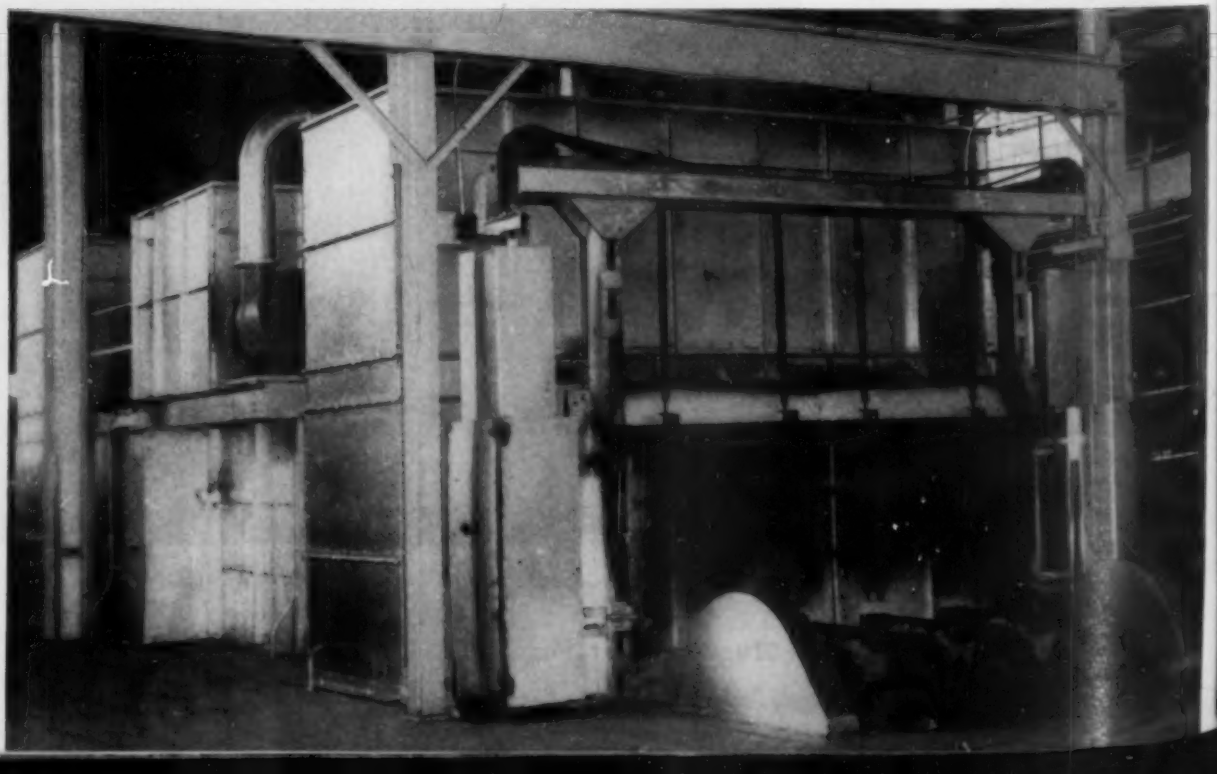
To permit very much cold work, annealing will be required. Additional intermediate anneals may also be required during the cold working process. This annealing is carried out, at temperatures ranging from 650 to 750° F., in batch type recirculating annealing furnaces, fired with either oil, gas or electricity (with gas preferred, because of its greater ease of control and lower cost). The furnaces are usually of the car or tray-and-dolly type, very similar to the units used for homogenizing.

As with all aluminum work, uniformity is extremely important, and for this reason recirculating type furnaces are universally employed. Uniformity of 5 to 7½° F. is commonly obtained.

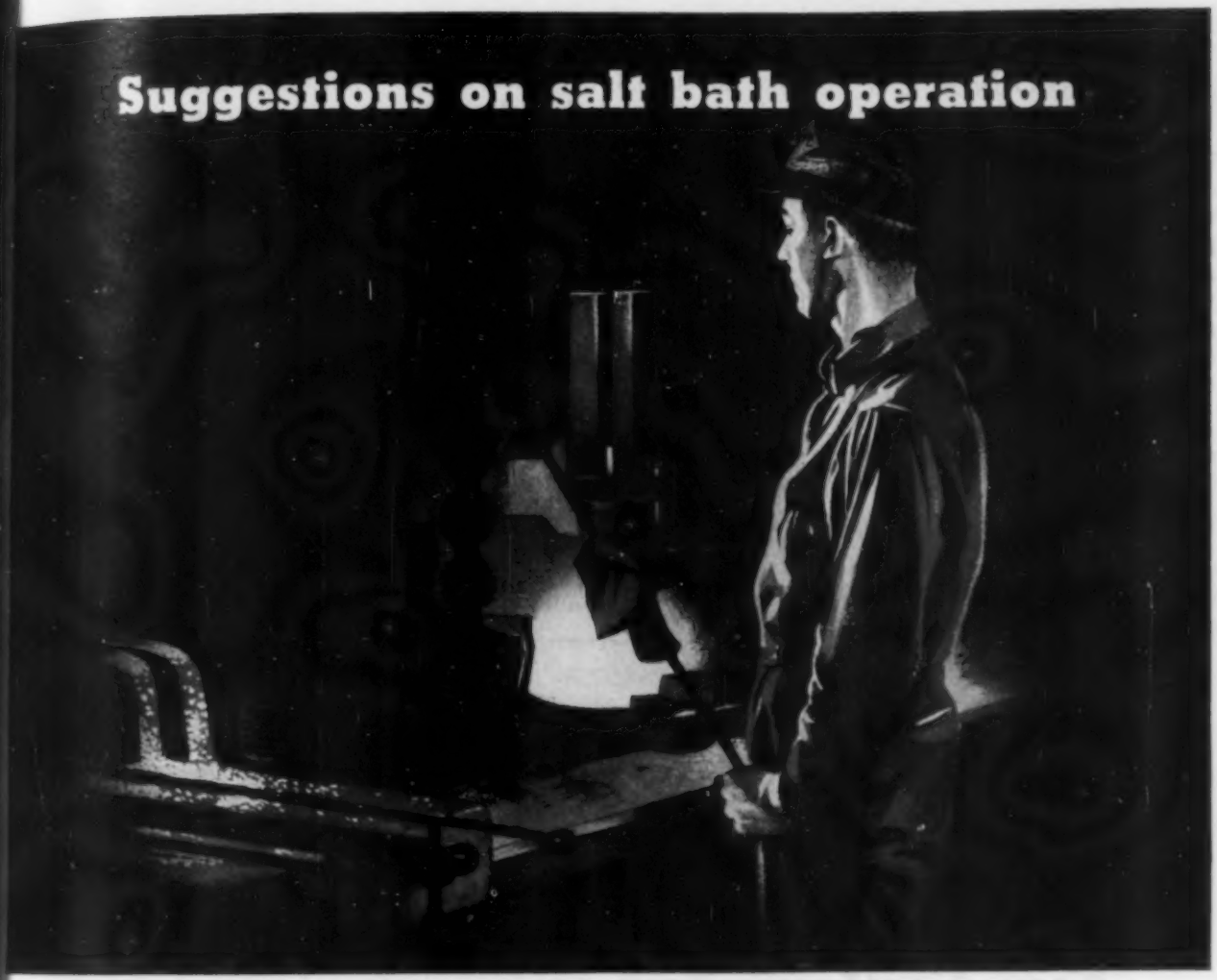
Conclusion

It is hoped that the foregoing brief outline of melting, casting, preheating and annealing will be of service to those handling aluminum alloys for the first time. No attempt has been made to go into the various operations in great detail, or to describe all of the variations practiced in special cases, but it is felt that a bird's-eye survey might have value at this time of so much activity in this particular field.

Fig. 6 — Recirculating Type of Furnace for Homogenizing or Reheating Ingots and Slabs of Aluminum Alloy



Suggestions on salt bath operation



Information supplied by an Industrial Publication

Properly used, the salt bath is a very effective means of preventing decarburization of high speed, carbon, and alloy steels during heat treatment. The following suggestions are offered as an aid to effective high speed tool steel heat treatment.

1. Clean work thoroughly. 2. Immerse in a preheat salt at 1500-1650° F. 3. Transfer to high heat bath at 2150-2250° F. 4. Immerse in quench bath at 1100-1200° F. After cooling to room temperature, wash in a hot alkaline cleaner, then reheat in salt to 1100° F.

To secure maximum pot life, (up to 3 years) use salts that are chemically neutral with refractory pots, and desludge bath periodically. Molten salt seals off all atmosphere, therefore decarburization, carburization, pitting, etching, or other surface defects can be avoided by using a suitable chloride salt and adding an acid rectifier. Several preparations are available containing rectifiers.

Adequate circulation in the bath is necessary to insure uniform temperature and prevent overshooting. Externally heated pots are not practical at high temperatures, so internally heated electrode baths, preferably with automatic, or electromotive, circulation are regarded as the most effective for mass production.

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PERSONALS

Elected to membership on the executive committee of the American Society for Testing Materials: F. G. TATNALL, manager, testing equipment department, Baldwin-Southwark Division, The Baldwin Locomotive Works, Philadelphia, chairman of the Philadelphia Chapter.

RAYMOND E. GLENN, formerly metallurgist, American Steel & Wire Co., Cleveland, is now metallurgical sales engineer, A. F. Holden Co., Detroit.

Promoted: FRANK L. WRIGHT, from chief metallurgist, Norma-Hoffman Bearings Corp., Stamford, Conn., to manager of research.

FRED J. WOOD, formerly in the Detroit office of Jessop Steel Co., has been appointed district manager in Toronto.

FRANCIS C. FRARY, director of research, Aluminum Co. of America, Pittsburgh, has been named honorary chairman of the 106th convention of the American Chemical Society, to be held in Pittsburgh Sept. 6 to 10.

Nominated as a manager by the American Society of Mechanical Engineers: SAMUEL H. GRAF, professor and head of mechanical engineering, Oregon State College, Corvallis, Ore., and a past chairman, Oregon Chapter.

WILBUR R. VARNEY has resigned as metallurgist and department superintendent of the Taylor-Wharton Iron and Steel Co., Easton, Pa., to accept a commission as lieutenant in the United States Naval Reserve.

WILLIAM H. MCCART is now associated with Cook Heat Treating Corp., Los Angeles, working on metallurgical and personnel problems.

FRANK A. MCCLINTOCK, M.S. in mechanical engineering, Massachusetts Institute of Technology, is now working as a junior mechanical engineer in the research division of United Aircraft Corp., Hartford, Conn.

GEORGE S. MCFARLAND has retired from active business and is making his home in Coventry, Vt.

CLAIR A. GORTON, formerly with the Standard Oil Development Co., is now in the metallurgical department of the Dodge Chicago Plant, Chrysler Corp., Chicago.

PETER F. LANGAN, formerly assistant works manager, Springfield Machine and Foundry Co., Springfield, Mass., is now superintendent of the Precision Engineering Co., Feeding Hills, Mass.

JOHN E. WALKER, formerly rod and wire mill metallurgist with the Pittsburgh Steel Co. is now an ensign in the United States Naval Reserve, stationed at Annapolis, Md.

ARTHUR M. MORGAN has been made vice-president and general sales manager for Latrobe Electric Steel Co., Latrobe, Pa.

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PERSONALS

WALTER BONSACK, chief metallurgist and director of research laboratories, the National Smelting Co., Cleveland, has been awarded the 1943 Dudley Medal of the American Society for Testing Materials in recognition of a technical paper of outstanding merit and original research.

GLENN SOWDERS, formerly with Massachusetts Steel Treating Corp., Worcester, Mass., is now in charge of heat treating, Illinois Division, Bendix Aviation Corp., Chicago.

Ensign MICHAEL LARINOFF, U.S.N.R., is serving as an engineering officer of a motor torpedo boat base.

C. B. MCLAUGHLIN now represents Tube Turns, Inc. of Louisville, Ky., in the Pittsburgh office.

HAROLD SMALLEN, formerly assistant metallurgist, Saginaw Steering Gear Division of General Motors Machine Gun Plant, is now an ensign in the United States Naval Reserve.

EDWARD N. CASE, formerly with A. F. Holden Co., is now head of metal trades laboratory, Stamford Research Laboratories, American Cyanamid Co.

NICHOLAS W. LUKSHA is now resident inspector, Twin Disc Clutch Co., Rockford, Ill.

RALPH W. ROGERS, JR. has been transferred from the New Kensington to the Cressona, Pa. works of Aluminum Co. of America, where he is serving as extrusion division metallurgist.

JAMES N. NUTT, JR. is employed as junior metallurgist in the metallurgical laboratories of the Wright Aeronautical Corp. at Cincinnati, Ohio.

R. I. GARDNER has resigned as chief engineer for the Eastman Instrument Co., Denver, Colo., to work for the Ryan Aeronautical Co., San Diego, Calif., in the manifold department.

SEYMOUR SCHWARTZ, formerly assistant process engineer at Ryan Aeronautical Co., is now with Interstate Aircraft and Engineering Co. as process engineer.

SAM TOUR of Lucius Pitkin, Inc., has been made manager of the new Minerals Division of Barium Stainless Steel Corp.

JAMES R. CADY, formerly foundry engineer and staff assistant, Columbia Steel Co., Pittsburg, Calif., is now working for Battelle Memorial Institute, Columbus, Ohio, as a research engineer.

CARL WESSEL, consulting metallurgical engineer, formerly manager of the metals division, George W. Borg Corp., Chicago, has opened a new shop in Chicago for instructing licensees on the "Wessel gravity die casting system".

H. P. BIGLER, assistant to the president, Connors Steel Co., Inc., Birmingham, Ala., has been named a member of the Rail Steel Mill Industry Advisory Committee to W.P.B.

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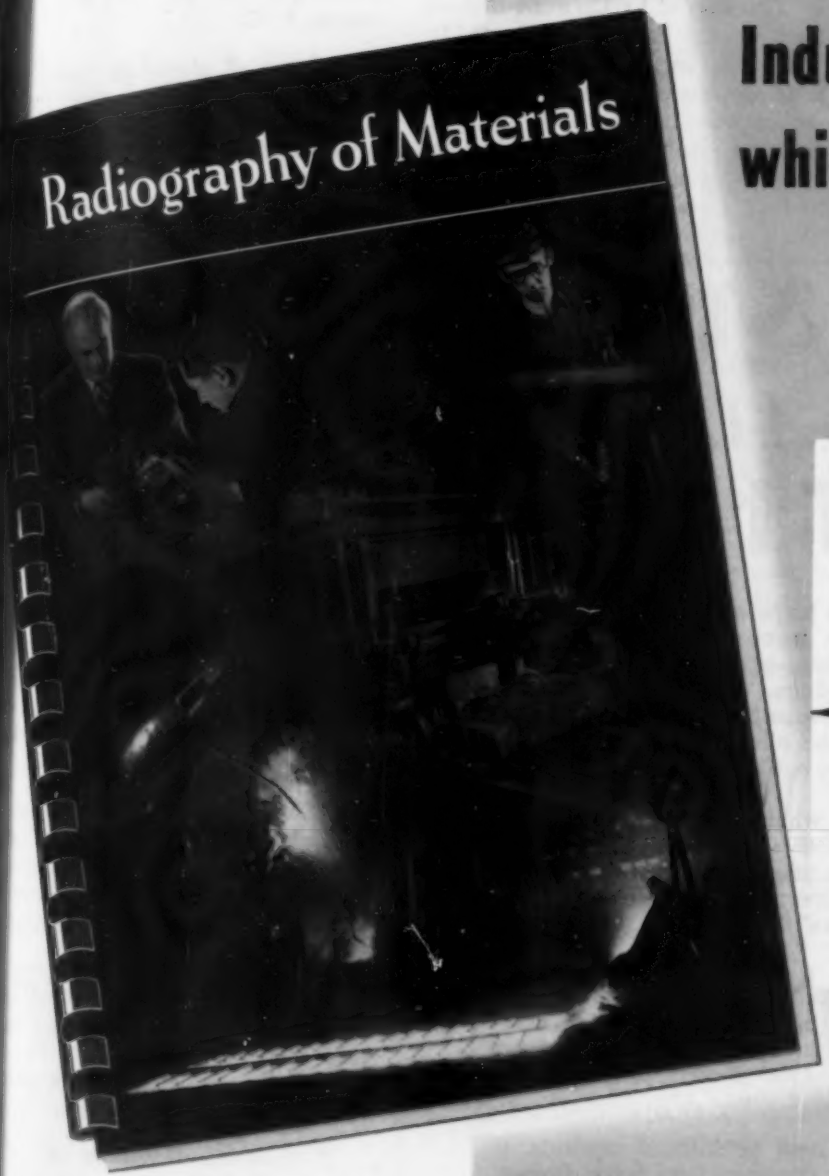

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Industrial Radiography
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General Physical Considerations
Intensifying Screens
X-ray Films and Their Uses
Exposure
Processing
Processing Room
Viewing Radiographs
Protection
Unsatisfactory Radiographs
Bibliography
Appendix 1—Characteristic Curves

The above table of contents outlines the scope of this new Kodak book on industrial radiography . . . and also indicates that most of its emphasis is naturally on films, and their exposure and processing. Based upon information supplied by the research and technical workers who have produced Kodak's line of industrial x-ray films, processing chemicals, and accessories, the book will be helpful toward their most effective use. For your free copy, write to

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PERSONALS

SAM TOUR, vice-president and chemical and metallurgical engineer in charge of the engineering departments of Lucius Pitkin, Inc., New York, has organized Sam Tour and Co., Inc., to take over operation of the metallurgical laboratories established by him in the Pitkin organization.

ROY ERWIN SWIFT, formerly instructor of metallurgy for the School of Mines, University of Alaska, has been appointed associate professor of chemistry for the same institution.

Transferred by Carnegie-Illinois Steel Corp.: R. K. BOWDEN, to Pittsburgh as director of quality control, research and technology department. L. J. ROHL, formerly assistant manager, succeeds Mr. Bowden as manager of the Chicago district metallurgical department.

GALE S. HANKS has resigned his position as senior engineer with Remington Arms Co., Denver, Colo., to accept a commission as ensign in the Ordnance Department of the U. S. Naval Reserve, stationed temporarily at the Navy Yard in Washington, D. C.

ARTHUR E. COTE, formerly with Van Norman Machine Tool Co., is now with the Reda Mfg. Co. of Springfield, Mass.

WAYNE S. COLMERY, formerly metallurgist with National Tube Co., Ellwood Works, is now chief metallurgist, Pacific Tube Co., Los Angeles.

ELLIS BLADE, formerly chief engineer, Spring Division of John Chatillon & Sons, New York, is now industrial engineer, Henry Mill & Timber Corp., Tacoma, Wash.

JAMES R. ADAMS has been appointed general superintendent of the Midvale Co.

JOHN A. HOLBROOK, formerly with Brown Instrument Co., is now affiliated with the Sperry Gyroscope Co. Research Laboratories, Garden City, N. Y., doing engineering work on aircraft instruments.

J. L. WAISMAN, formerly metallurgist at the Berwick plant of American Car and Foundry Co., is now metallurgist for the Chicago plant of the Douglas Aircraft Co.

CLARENCE E. LEVOE, a recent graduate of Colorado School of Mines, has been appointed to the staff of Battelle Memorial Institute, assigned to research on high temperature properties of metals.

J. HASBROUCK WILSON, formerly with J. C. Joyce and Associates, South Gate, Calif., is now engineer, Advance Tool Engineering Co., Los Angeles.

ELMER GAMMETER, past chairman, Chicago Chapter, has resigned his position as manager of the stainless steel bureau, Chicago District Metallurgical Division, Carnegie-Illinois Steel Corp., to become chief metallurgist of Globe Steel Tubes, Milwaukee. RUSSELL B. GUNIA, formerly contact representative, succeeds Mr. Gammeter as manager of the stainless steel bureau.

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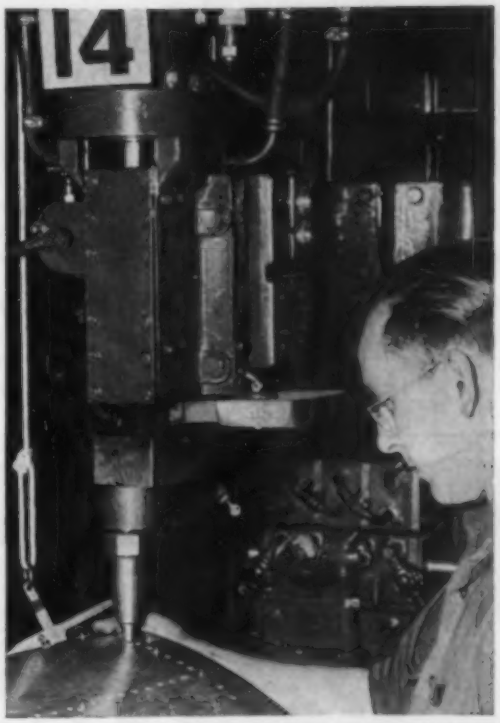

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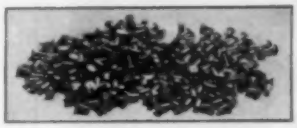

Spot welding saved all these rivets which would normally be required to assemble the Curtiss P-40 belly cowl.

Thanks to phenomenal advances in machines and techniques, aircraft manufacturers have replaced slow, costly riveting with speedy, economical spot welding. This is true not only of non-structural parts such as door and window frames, seats, engine and nacelle cowling—but also of primary stressed assemblies including floor supports, wing ribs and stabilizer leading edges.

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	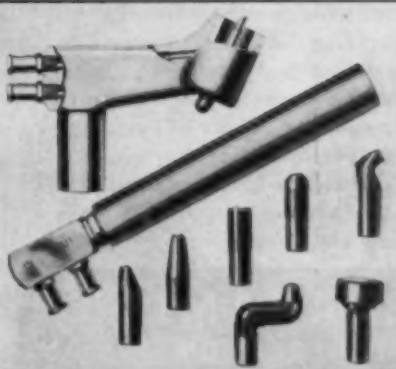	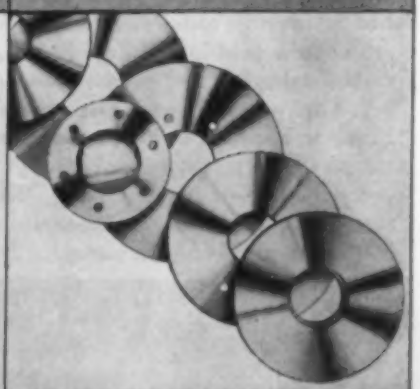

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HEALTH ASPECTS OF WELDING

(Continued from page 253)

are a serious hazard and require special protection, for such fumes may produce a pulmonary irritation and edema (swellings from trapped fluids) resembling in many ways the effects from inhaling oxides of nitrogen.

Many other metals have been mentioned as injurious — manganese, chromium, cobalt, copper, tin, antimony, magnesium, aluminum, tellurium, vanadium, titanium. As encountered in welding fumes the amounts are usually definitely less than those known to have toxic effects. Other materials than gases or metals may create fume hazards through air contamination. These may be encountered especially in repair work on various tanks or vats; their presence calls for special ventilation. Such closed vessels should always be thoroughly cleaned, or filled almost completely with water to avoid possibility of explosion.

One other source of real hazard is the presence of fluorides in many of the fluxes or rod coatings used for aluminum. Hydrofluoric acid may be formed and the fume if inhaled in appreciable concentrations or for long periods may cause considerable irritation to the nose and throat or pulmonary edema.

To sum up: The real hazards of welding are not many, are generally easily identified and protective measures are available and effective when used. Briefly they are due to:

1. Radiant energy — ultraviolet and visible light.
2. Oxides of nitrogen.
3. Fumes of lead, cadmium and zinc.
4. Fumes from organic residues or wastes.
5. Fumes from fluoride-containing fluxes and rod coatings.

Welding out of doors or in large shops seldom results in any serious air contamination except in the case of lead. In spaces of less than 1000 cu.ft. and especially inside tanks or ship holds, special ventilation is necessary. Usually the exhaust of contaminated air is much more effective than an attempt to force fresh air into the space.

In the case of gases such as oxides of nitrogen, or the rare instances of carbon monoxide, if ventilation is maintained from the beginning of the operation sufficient to insure good visibility and to insure a comfortable temperature there should be no gas hazard even in confined spaces. If lead or cadmium fumes are present the only complete protection is by gas masks supplied with a stream of fresh air under light pressure.

Briefly, a minimum standard of ventilation is one that will be sufficient to insure good visibility at the point of operation, and insure a temperature within a reasonably comfortable limit. In confined spaces this would call for exhaust ventilation. In case of lead or cadmium exposures, air-supplied masks are required. No serious hazard is apt to be present except in confined spaces or when lead is encountered. Ventilation requirements are given in more detail in Special Bulletin No. 5 of the U.S. Department of Labor, "Control of Welding Hazards in Defense Industries".

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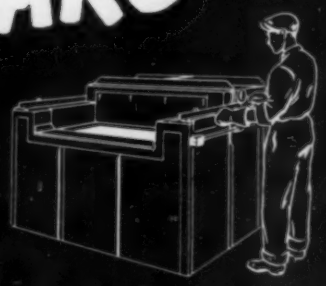

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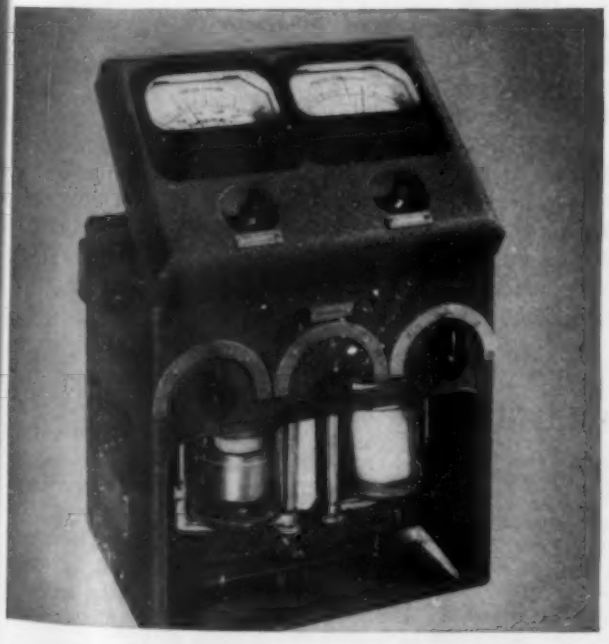

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CARTRIDGE BRASS

(Continued from page 248)

enough for excessive grain growth. As a rule, 30 min. to 1 hr. is enough time *at* temperature, once all the metal has been heated. To reiterate, annealing time is composed of time to get the charge to temperature *plus* the time at which grain growth is proceeding.

In summation of the variables affecting annealing, it may be said that changes in prior cold working, metal cross section, or metal weight charged must be compensated for in the schedule, if consistent results are to be maintained.

The question may well be asked, "How much control over grain size must be exercised?" The answer is not without qualifications: It all depends! The minimum grain size will usually be established by the cold working operations in the plant. Too small a grain size results in breakage; perhaps resulting "physicals" for a small grain size are wrong; probably elongation is too low — though if the specification controls the tensile strength, this may be too high. Therefore, annealing conditions are established to produce the minimum grain size to meet these production needs, and are usually set at a slightly higher temperature than the absolute minimum for an adequate safety factor.

On the other hand, the maximum grain size will depend on more complex factors. In the first place, the actual measurement of the average grain size becomes less accurate as the absolute value increases. For example, at 0.150 mm. some grains are considerably smaller than the average and some larger. Consequently, a tolerance of 0.050 mm. would not be excessive, as compared to ±0.010 mm. at 0.030 mm. average specified.

Secondly, grain size control depends on the cold forming operation on at least three counts: *(a)* The larger the grain size the rougher the surface after working, especially if no "ironing" between tool surfaces is done as at the end of a punch. "Orange peel" results, a condition which is nearly self-descriptive, the surface being rough, much as an orange skin. If the part is subsequently polished or a smooth surface is necessary, the smallest grain size that will work without breakage is preferred. *(b)* Close control is indicated with certain types of operations. A large grain size will cause breakage just as too small a grain size will. We have had examples of deep drawing in which 0.030 mm. was too small, breakage occurring, as was 0.050 mm. for the same reason. Again, close control is indicated. *(c)* If minimum hardness or tensile strength is required, then grain size cannot be allowed to become so large that its value falls below specification.

Consequently, the conditions of operation will determine the degree of control needed and each case must be determined in the light of all requirements. In any event, it is hardly economical to heat metal so hot as to produce very large grain sizes.

While much of the foregoing has specifically referred to strip, cartridge brass is used in rod and tube form for many articles requiring forming of some description, for rod such as cold extrusion or cold heading, and for tubing for bending and flanging. In any case, the foregoing principles apply.

A Complete ALLOY CASTING SERVICE

Production of alloy steel castings is a fussy job...requiring extremely close control over each step in the process. Raw materials are checked against rigid specifications...moisture content of sand is precisely controlled...pouring temperatures are closely regulated. Result? Sound castings...free of cracks, surface defects, cold shuts or seams.

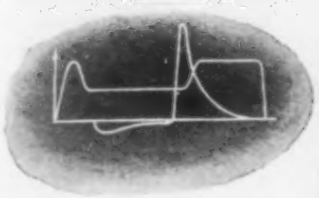
Since 1922 The Cooper Alloy Foundry Co. has specialized in the production of stainless steel, monel, nickel, chrome-iron, chrome-nickel and other alloy castings. We offer users of castings resistant to corrosion, heat and abrasion, a complete alloy casting service... production "know-how" plus practical assistance in the selection of proper alloys. You can get sound castings from Cooper that are "right" for your application.

THE Only ALLOY FOUNDRY WITH All THESE FACILITIES

- Laboratory control over raw materials and finished products.
- Dual foundry...both hand and machine molding.
- Heat treating of castings up to six feet in size.
- Machine shop . . . specially equipped for finishing stainless steel.
- Improved cleaning . . . including Lustracast electrolytic finishing which leaves all surfaces bright.
- Castings furnished rough, polished or fully machined . . . one ounce to two tons.
- Development of special alloys to meet unusual requirements.
- Technical consulting service.

THE Cooper ALLOY FOUNDRY CO.
115 BLOY STREET • HILLSIDE, NEW JERSEY

HELPING TO SOLVE TODAY'S WARTIME PRODUCTION PROBLEMS



the problem of spot-welding heavy gauges

ON ALUMINUM AND LIGHT ALLOYS

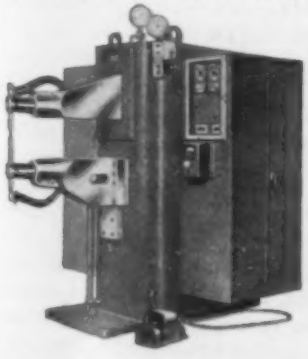
It is not generally recognized that the spotwelding of heavy gauge aluminum on a production basis is being successfully accomplished today. Many leading aircraft manufacturers are speeding up the fabrication of heavier assemblies by employing the Sciaky Process of Electric Resistance Welding.

Inasmuch as the difficulties involved in the spot-welding of aluminum increase proportionately with the increase in thicknesses used, the advantages of the Sciaky Stored Energy Principle and Variable Pressure Cycle can be readily seen. The extremely high current requirement is compensated for by the use of Stored Energy, which effects high power factor, uses less current and balances the three-phase supply.

The tremendous pressure required is obtainable by the use of a special, heavy duty head using two cylinders. These can operate either on the Variable Pressure Cycle or at constant pressure. When both cylinders are operated at constant, the maximum pressure can be made as high as 12,000 lbs.

Exhaustive tests have demonstrated the ability of the Sciaky 240 KW machine to weld satisfactorily two thicknesses of .156" aluminum in production. Under proper conditions, two thicknesses of .187" aluminum can also be fabricated by this method.

* *

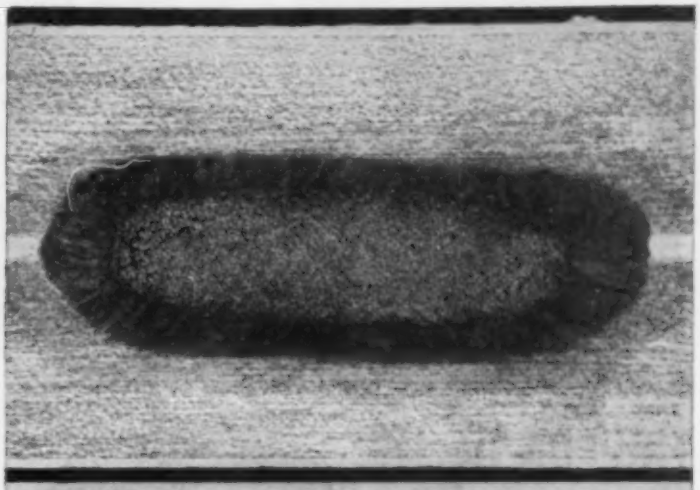


TYPE PMCR2S-5 SCIAKY ELECTRIC RESISTANCE ROCKER ARM WELDER, with built-in rectifier, welding 70 spot welds per minute on two sheets of aluminum alloy of .040" each. Welding capacity: from two thicknesses of .016" in aluminum alloys up to and including .080".

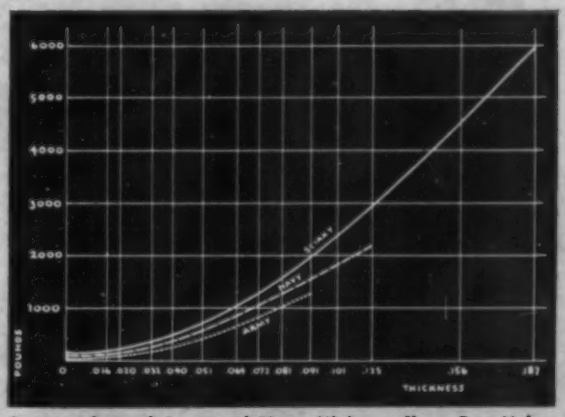
SCIAKY BROS.

Manufacturers of a Complete Line of A.C. and D.C. Electric Resistance Welding Machines.

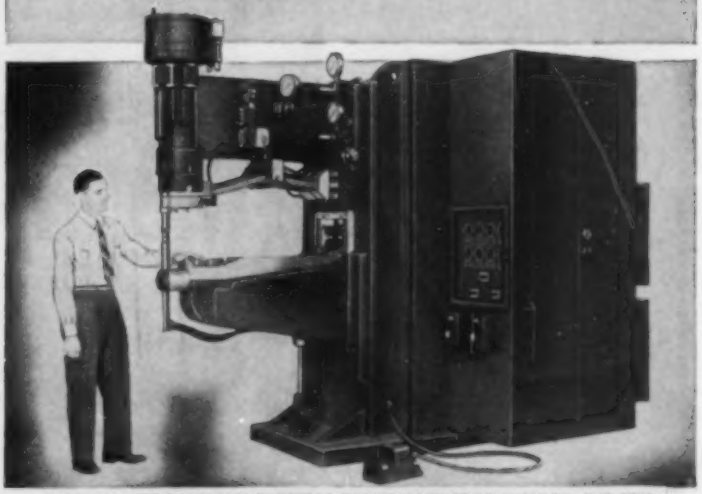
4915 W. 67TH ST. • CHICAGO, ILLINOIS



UNRETOUCHED MACROPHOTO of a typical Sciaky spot weld on .156" plus .156", 24ST Alclad at 14X Mg., indicates the weld nugget of proper penetration, and a central zone of uniform cast structure surrounded by an even columnar zone. Good grain structure with no porosity and the absence of cracks is also evident.



A comparison of Army and Navy Minimum Shear Test Values and the range of Sciaky Machines.



TYPE PMC05S-1 SCIAKY ELECTRIC RESISTANCE SPOT WELDER, 240 KW. Welding capacity: aluminum and other alloys or corrosion resisting steels in thicknesses of from .040" plus .040" minimum up to and including .187" plus .187" maximum. Speed: 40 spot welds per minute on two thicknesses of .040" of light alloys.

THIN CASES

(Continued from page 261)

surface of the work, then the coupling factor is 0.5 and only half the primary ampere-turns, or some 500 amperes in the one-turn secondary circuit, are available for generating heat in the work. Since the heating rate in watts equals I^2R and since the current has already been determined by the primary ampere-turns and the coupling factor, it follows that the rate of heating in the metal can only be increased by increasing the resistance of the surface layer in which the current is confined.

The only way this is possible is to decrease the thickness of the layer of metal which is carrying the current, and this is done by increasing the alternating frequency. It can be shown that if the operating frequency is increased from 1 megacycle to 4 megacycles, the thickness of the current-carrying surface layer is reduced one-half. Therefore, the secondary resistance through which the 500 amperes must flow is doubled, and the heat developed in the surface layer by this current is also doubled. At the same time, the heated zone has been restricted to half the depth below the surface it occupied at the lower frequency.

The above example brings out a fundamental reason for high frequency in surface hardening. There will always be a frequency converter of limited output, an induction heating coil with a limited current-carrying capacity, a finite number of turns, and a coefficient of coupling between the work and the coil whose value for practical design purposes is also fixed. All the above restrictions will limit the magnitude of the secondary current. There remains to the metallurgist only the control of the secondary resistance by exploitation of high-frequency skin effect.

These considerations are of prime importance as the part to be heat treated becomes smaller. It results therefore that thin surface layers on end bushings on a 0.63-in. hollow spindle of 0.35% carbon steel with 0.12-in. walls can be heated by radio frequency currents in 0.7 sec.; self-quenching causes hardness of Rockwell C-55. Hardened layer is about 0.001 in. thick and is quite uniform; the transition zone from hard case to unaltered core (estimated by dark etching on polished cross section) is about 0.0003 in. thick.

The very short time at heat is insufficient to put all of the carbides into solution, and the combination of hard martensite and carbide particles in a low carbon steel (0.35%) surface — placed under compressive stresses — may have some interesting properties in special services. Time is also so short that only a slight blue coloration appears on the surface. Heat changes are so localized and uniformly balanced that there is no measurable distortion. Hence the treatment can be given to finish-ground parts. Likewise the operation can be made fully automatic as to loading, heat treating, and ejection, and — if coloration is undesirable — performed in controlled atmosphere. The space requirement of a vacuum tube oscillator is small. Its power supply can be located at a remote point, and its work load can be either located at the oscillator or coupled to it from a distance by means of a grounded concentric line.

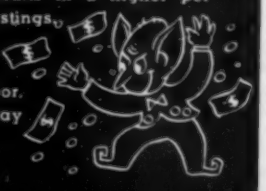
A DETROIT ELECTRIC FURNACE SPOILS THE FUN OF THE FOUNDRY GREMLINS

REDUCES METAL LOSSES. The Detroit Furnace was originally developed to conserve the nation's metal and fuel deposits. This is accomplished through fast, efficient melting with lower melting losses and the foundry use of salvage materials.

SAVES LABOR. Fast melting assures a high rate of production per man hour. No fuel to handle or store plus less dross and slag to handle for secondary metal recovery result in lower, indirect labor costs.

SAVES FLOOR SPACE. Compact, fast and efficient Detroit Furnaces give high production per unit of floor space.

REDUCES NUMBER OF REJECTS. Through accurate metallurgical control a Detroit Furnace improves metal quality and results in a higher percentage of finished perfect castings.



SAVES MONEY. Detroit Furnaces save time, labor, materials, floor space and plant equipment. Write today for complete facts.

DETROIT ELECTRIC FURNACE DIVISION

KUHLMAN ELECTRIC COMPANY • BAY CITY MICHIGAN

WHERE TEMPERATURES SOAR . . .

AND ACIDS CORRODE . . . USE

FAHRITE

HEAT AND CORROSION RESISTING ALLOYS

Infernos blaze across the nation as tools of war receive their baptism of fire and acid. In hundreds of these man-made hells, where temperatures soar to fantastic heights and chemicals do their swift, corrosive work, you'll find FAHRITE castings on the job. This alloy is the result of twenty-one years experience and constant research and development by the engineers, and metallurgists, of The Ohio Steel Foundry Company.

The abilities of FAHRITE to resist heat and corrosion can help YOUR war-production. Our engineers will gladly work with you in the creation of the FAHRITE part or parts that will serve your needs precisely. Write us for complete information.

ARMY E NAVY

THE OHIO STEEL FOUNDRY CO.

ENGINEERS • FOUNDERS • MACHINISTS

LIMA AND SPRINGFIELD, OHIO

FREE ENTERPRISE IS THE ONLY WAY TO CONSTANTLY HIGHER AMERICAN LIVING STANDARDS

NEW PRODUCTS

Furnace Atmosphere Indicator

A new atmosphere indicator, based on the thermal conductivity, has been devised by Claud S. Gordon Co. of Chicago, and manufactured by Weaver Mfg. Co., Springfield, Ill. The ideal atmosphere for a given furnace operation, once determined, can be reproduced for any similar operation by adjusting the air-fuel ratio to give the same indicator reading.

Glass Tanks

New line of glass tanks, built to required shape and size of heavy plate glass, tempered for shock resistance, is announced by Pittsburgh Plate Glass Co., Pittsburgh. Such tanks are usually surrounded by a protective framework, and will stand continuous operating temperatures of 650° F. Such tanks have proven serviceable in pickling steel and other metals.

New Pickling Machine

Designed for increased production of shells, a continuous, drum-type pickler has been developed by the Howard Engineering & Mfg. Co., Cincinnati, capable of pickling 37-mm. shell cases at the rate of 8000 an hr. Cases travel through the machine in a drum which varies in diameter so that each section runs in its particular tank, successively pickling, rinsing, neutralizing and washing. Pumps are not required, as the solutions are picked up by scoops on the side of the drum. Machine is 35 ft. long, 8 ft. wide and 9 ft. high.

Carbide Grinder

New floor type carbide grinder (with a heavy base, drum type on-off-reverse switch, heavier tables, and storage compartment for wheels and tools) has been announced by Thomas Prosser & Son, 120 Wall St., New York City. New machine removes metal rapidly when rough grinding, as well as accurately finishing all single-point tools to smooth, keen cutting edges with flat surfaces, held exactly to desired angles. Either silicon carbide or diamond wheels can be used for grinding carbide, or aluminum oxide wheels for grinding stellite or high speed steel. Prompt deliveries can be made.

Increases Cutting Work

A shop-built device for multiplying productive output of a portable radiagraph cutting machine accomplishes the work normally produced by two or more machines in a New England shipyard. As shown in the photograph at bottom, right, the attachment consists of a 10-ft. bar balanced crosswise on an Air Reduction radiagraph, with ends supported cantilever fashion by turnbuckles welded at the apex to a plate. This bar carries four adjustable torches for trimming parallel edges simultaneously on two plates, one on each side of the machine tracks.

Washing Equipments

Working with a manufacturer of gyroscopes for airplanes, American Foundry Equipment Co. of Mishawaka, Ind., has developed a machine to clean and oil small bearings without exposing them to room air or handling, which would result in rusting from finger smudges. The

bearing races vary from ¼ in. outside diameter up to 1¼ in. This washer consists of a solvent container, a small solvent pump, a filter, and the proper adapters.

Another new American Foundry development is the "Tabl-Spray" metal washer for fast washing of flat, fragile work, or parts with intricate crevices. Typical applications include removing lapping compound from magnesium and aluminum aircraft parts, cleaning crankcases, supercharger rear housings and adapters, small assemblies, gears, or rocker arms — prior to inspection or after magnaflux.

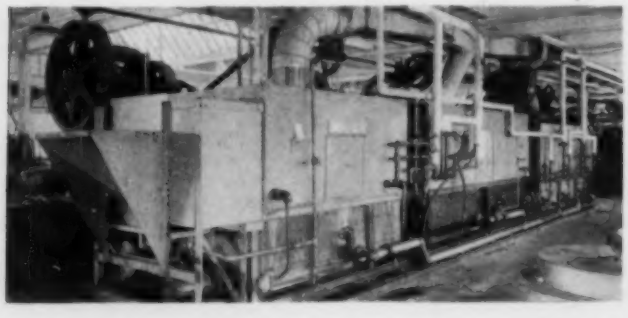
Rivet Gun

G15 gun, manufactured by Cherry Rivet Co., Los Angeles, is especially for Cherry blind rivets. Tests show that 1600 rivets can be driven in an hour with this tool.

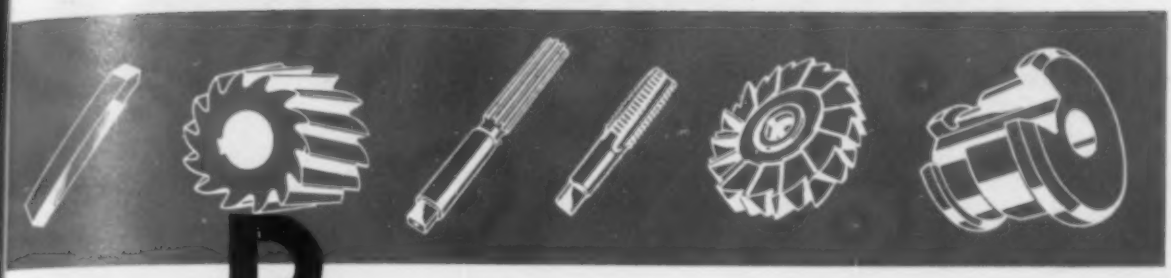
Degreasers

Complete line of standard and specially designed vapor and solvent degreasers is now offered by the Magnus Chemical Co., Garwood, N. J. Just announced is a new portable multi-purpose washing

(Continued on page 316)



C-O-N-S-E-R-V-E



PRECIOUS TOOLS

by Salt Bath Final Case

Tools are vital. Their life must be lengthened to keep our armament program on schedule.

As a result of several years' experience with heat treatment of high speed steels, Houghton offers a simplified, final heat treatment which is producing phenomenal results. From 200 to 300% increase in tool life is usual when this liquid bath is used to form a superficial hard case after the conventional heat treatment.

Liquid Heat No. 720 is fluid at 920° F., and is used between 1000 and 1050° F. for periods varying from 10 to 90 minutes. A nitride penetration from slightly under .001" for the shorter time, to .002" for the longer periods, provides the extra protection that greatly lengthens the time between grinds.

This treatment does not change dimensional sizes when previous heat treatment was completely effective. Cost is low, results astounding in longer tool life. Write for full details of the preservation of vital tools by liquid nitriding.

E. F. HOUGHTON & CO.
303 West Lehigh Avenue
PHILADELPHIA

Offices in all Principal Cities in the United States and Canada

HOUGHTON'S

LIQUID HEAT

NEW PRODUCTS

(Continued from page 314)

machine for cleaning a wide range of large and small parts. This new machine is designed to meet the needs of metal fabricators whose production rates do not warrant the installation of large, fully automatic, washing equipment.

This company has also developed a new metal coating compound, preparatory to drawing. Material is applied as a dip coating to high or low carbon steel wire, copper coated wire and stainless steel wire after pickling. For further information write the company, attention Dept. MP.

Prepares Galvanized for Paint

Paint adheres to galvanized metal — with no chipping or peeling — if the galvanized surface is wiped or dipped in "Turco Redi-Paint", according to Turco Products, Inc., of Los Angeles and Chicago. In but a few seconds, the

surface is passivated. A unique feature is a dark tint that develops on areas properly treated, leaving the untreated area bright.

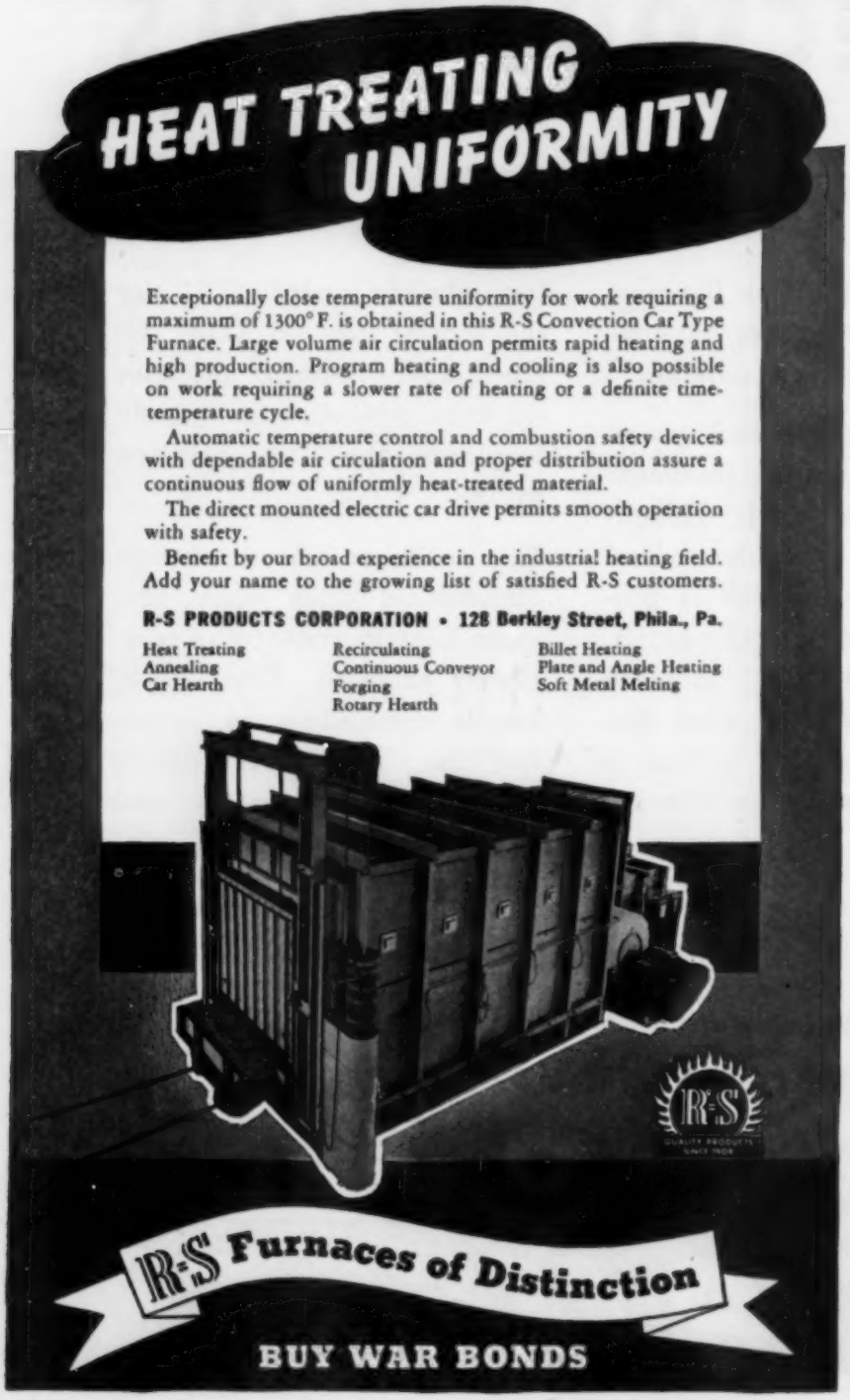
Tool Room Furnace

Hardening and carburizing furnace for small tools and parts is announced by Industrial Furnace Div., Lee Grinder Co., 4708 Armitage Ave., Chicago. Furnace is of the bench type and particularly designed for use with accelerated carburizing salts. Maximum temperature is 1600° F.

Hardness Tester

Hardness tester has been introduced by Clark Instrument, Inc., 10200 Ford Road, Dearborn, Mich., featuring a frictionless spindle which provides a correct minor load; zero drag trip which eliminates friction on the loading beam, insuring consistent accuracy of the major load; a simple indicator

adjustment for maintaining accuracy of readings; and a minor load adjustment. Three anvils are included — a standard 3½-in. anvil for large flat bearing surface work, a spot anvil for most standard size pieces and for test blocks, and a "V" anvil for testing round and cylindrical parts.


HEAT TREATING UNIFORMITY
Exceptionally close temperature uniformity for work requiring a maximum of 1300° F. is obtained in this R-S Convection Car Type Furnace. Large volume air circulation permits rapid heating and high production. Program heating and cooling is also possible on work requiring a slower rate of heating or a definite time-temperature cycle.
Automatic temperature control and combustion safety devices with dependable air circulation and proper distribution assure a continuous flow of uniformly heat-treated material.
The direct mounted electric car drive permits smooth operation with safety.
Benefit by our broad experience in the industrial heating field. Add your name to the growing list of satisfied R-S customers.
R-S PRODUCTS CORPORATION • 128 Berkley Street, Phila., Pa.
Heat Treating
Annealing
Car Hearth
Recirculating
Continuous Conveyor
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R-S Furnaces of Distinction
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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Powdered metal presses producing millions of metal parts illustrated in catalog by Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin 6.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Illustrated data information on cutting oils and their correct use. National Refining Co. Bulletin 9.

"Dag" colloidal graphite as a high temperature lubricant. Acheson Colloids Corp. Bulletin 248.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Forty different ways to cut machining costs. Continental Machines, Inc. Bulletin 11.

Properties, applications and use of hard-facing rods. Coast Metals, Inc. Bulletin 249.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Grinding and polishing with abrasive belts. Hammond Machinery Builders, Inc. Bulletin 13.

Handbook on aircraft riveting. Cherry Rivet Company. Bulletin 14.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

265-page textbook covers techniques used in contour machining, laboratory controls in manufacture of precision saw bands. Doall Service Co. Bulletin 16.

Precision grinding wheel. American Emery Wheel Works. Bulletin 17.

Brazing of cemented carbide tools. Carboloy Co. Bulletin 18.

Cutting Fluids. Pate Oil Co. Bulletin 19.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

New catalog illustrates standard, non-standard, and special tools, shows prices of tools and blanks. McKenna Metals Co. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

Abrasive belt polishing machines. Divine Brothers Co. Bulletin 22.

Abrasive cloth gadgets. Behr-Manning Corp. Bulletin 23.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin 251.

20-page booklet on cutting fluids has been issued by Tide Water Associated Oil Co. for the metal working industry. Bulletin 252.

Many applications for the Norton open structure grinding wheel are shown in leaflet issued by the Norton Co. Bulletin 253.

New catalog describes metal forming machinery engineered and manufactured by the Yoder Co. Bulletin 254.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Parsons oval bag dust arrestors are described and 12 advantages listed in folder issued by Parsons Engineering Corp. Important advantage is reclamation of valuable dust. Bulletin 228.

FERROUS METALS

New war time edition of the machinery steel selector has just been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin 256.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 24.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels, Molybdenum Corp. of America. Bulletin 26.

New corrosion data work sheet acts as check list to insure consideration and evaluation of all factors influencing corrosive action. International Nickel Co. Bulletin 27.

Chemical analyses, shapes and sizes of Joslyn stainless steel products are presented in extras and deductions booklet just issued by Joslyn Mfg. and Supply Co. Bulletin 297.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 321, 322, 324, 326, 328, 330, 334, and 336.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio August, 1943

Send me the literature I have indicated below.

Name ..... Title .....

Company ..... Address .....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 9 pages.

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20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**	320	

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Enduro stainless steels. Republic Steel Corp. Bulletin 28.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin 29.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Die Steels. Latrobe Electric Steel Co. Bulletin 32.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin 34.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Four Coppco tool steels. Copperweld Steel Co. Bulletin 36.

Stainless steel. Allegheny Ludlum Steel Corp. Bulletin 37.

New process embodying both chemical and temperature controls for production of low carbon open hearth case carburizing steel is described in bulletin by W. J. Holliday & Co. Bulletin 38.

Shop notes on the machining of stainless steels. Rustless Iron & Steel Corp. Bulletin 39.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Cromoco air-hardening die steel for high production is described in new leaflet by Firth-Sterling Steel Co. Bulletin 257.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin 258.

NON-FERROUS METALS

Reynolds Metals Co. has issued two color charts showing marking for identification of wrought aluminum alloy products, rod, bar, tubing and shapes, and for aluminum alloy sheet. Bulletin 294.

Heat treatment of aluminum bronzes. H. Kramer & Co. Bulletin 259.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Bronze. Frontier Bronze Corp. Bulletin 44.

Copper Alloys. American Brass Co. Bulletin 45.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin 46.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin 47.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin 50.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin 53.

Surface protection for magnesium. American Magnesium Corp. Bulletin 54.

Standard specifications for all grades of aluminum alloys (casting grades only). Federated Metals Div., American Smelting and Refining Co. Bulletin 55.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Everyone joining nonferrous metals needs the new 12-page Westinghouse Brazing Booklet, crammed with timely ideas for saving man-hours and critical materials. Westinghouse Elec. & Mfg. Co. Bulletin 57.

"The Story of Magnesium" is name of illustrated booklet issued by the Permanente Metals Corp. Bulletin 261.

WELDING

"Sureweld" protected arc electrodes. Hollup Corp., division of National Cylinder Gas Co. Bulletin 58.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Electrode quantity and welding time graph. Arcos Corp. Bulletin 61.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Sciaky radial portable welder. Sciaky Brothers. Bulletin 63.

Flexarc A-C welders. Westinghouse Electric & Mfg. Co. Bulletin 64.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Shield Arc electrodes. McKay Co. Bulletin 67.

New Advances in Arc Welding Equipment Design. Harnischfeger Corp. Bulletin 68.

Precision welder. Hercules Electric & Mfg. Co., Inc. Bulletin 69.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

New "200" welder is described by Allis-Chalmers in Bulletin 260.

New JR shape cutting machine is described in new folder by National Cylinder Gas Co. Bulletin 233.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

Illustrated leaflet shows several welding positioners manufactured by Ransome Machinery Co. Bulletin 239.

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 241.

Welding alloys and metals on which they should be used are shown in helpful chart form by Eutectic Welding Alloys Co. Bulletin 242.

32-page catalog describes line of welding equipment offered by Victor Equipment Co. Bulletin 245.

TESTING & CONTROL

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Fixtures and accessories to extend usefulness of X-ray quartz analysis apparatus. Philips Metalix Corp. Bulletin 262.

Metallurgical polishing equipment by Tracy C. Jarrett. Bulletin 295.

X-Ray accessory and supply catalog. Picker X-Ray Corp. Bulletin 73.

Radiographic identification of negatives with lead markers. H. W. Knight & Son, Inc. Bulletin 74.

Electric heaters and controls for industrial and laboratory. American Instrument Co. Bulletin 75.

12-page catalog describes electric motor valve operators as applied to standard temperature control systems for fuel-fired furnaces. Automatic Temperature Control Co. Bulletin 263.

Carbon-Meter for rapidly determining carbon at the furnace. E. Leitz, Inc. Bulletin 264.

Convertible free-vane air-operated controllers. Bristol Co. Bulletin 265.

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin 77.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin 80.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin 81.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin 87.

Surface Analyzer. Brush Development Company. Bulletin 88.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

X-Ray metallurgical laboratory service. Claud S. Gordon Co. Bulletin 90.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Gas analysis. Burrell Technical Supply Co. Bulletin 92.

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Identometer for rapid identification of steel. Dravo Corp. Bulletin 267.

New condensed catalog gives prices and descriptions of instruments offered by Wheelco Instruments Co. Bulletin 268.

Eberbach micro hardness tester is illustrated and described in new booklet by Eberbach & Son Co. Bulletin 269.

Use Handy Coupon on Page 318 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 318, 321, 324, 326, 328, 330, 334, and 336.

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Data Sheet

Subject: Practical Application of Induction Heating Principles — Part 4 **Sheet No. 6**

INDUCTION HEATING ON CONVEYOR TYPE FIXTURES

All the data covered thus far have concerned the heating of metal when it was held in some definite position with respect to the heating coil. While this is necessary when large amounts of power are to be concentrated in a small surface area, there are many instances when the metal can be heated by continuously passing through a coil instead of remaining stationary in the coil during the heating cycle and then being removed. Included in this group are all through heating applications, whether they be for hardening, brazing, forging or annealing.

In order to apply this principle, let us consider the heating of a number of pieces placed in a long single turn coil in such a manner as to undergo similar magnetic excitation. When high frequency current is passed through this coil, these pieces slowly heat to any desired temperature depending upon the length of time they are subjected to the magnetic flux, and attain the same resultant heat distribution regardless of their respective position in the coil. Hence, if the metal piece occupying an end position were gradually moved towards the opposite end, the heating would be the same as when the piece remained stationary for an equal time cycle. This principle makes it possible to obtain the same results by passing the work through a coil of this type as those effected by placing the metal in the coil.

It also makes it possible to introduce cold metal into the coil at a constant rate and thus draw maximum energy from the source of high frequency current. This is contrary to the usual falling off of load as the temperature of the metal rises causing a loss of magnetic properties and resultant diminishing of the flux density. Consequently, more production is obtained from a high frequency generator of given output capacity.

The solution of the problem now hinges upon a coil of such design to permit the pieces to be continually fed in and out of the coil. The first step in the evolution of such a coil from our straight single-turn loop, would be to bend the end of the coil vertically and so form a bridge which would carry the current from one parallel side to the other and still permit a continuous entrance and exit of metal parts. This, however, would produce a strong magnetic field at the so-called "bridges" which would tend to distort the heat pattern. To overcome this, the bridges are extended to form loops and the field intensity at the center of the loop is sufficiently weakened to prevent a change of heat pattern.

This type of coil need not be limited to a single turn, since a coil of two or more turns can be formed in the same manner. An

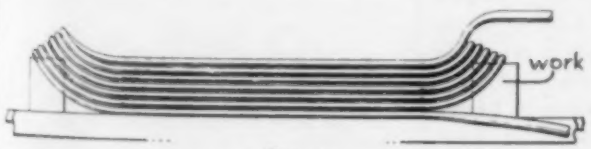

FIG 1

example of a multi-turn conveyor-type coil is shown in Fig. 1. The number of turns, of course, would depend upon the requirements for the heating of the specific parts involved. The relative position of the turns of the coils with respect to each other can be varied along the length of the coil to give any desired heat pattern. This might permit the whole piece to be heated during the first part of its travel through the coil and only a restricted area to be heated during the last part of the heating cycle.

Where very close control of the heat pattern is desired and the parts to be heated are circular in cross section, the pieces may be rotated as they pass through the coil to insure uniformity of the heat pattern around the periphery of the piece. This is simple to achieve from a mechanical standpoint and lends greatly to the effectiveness of the coil for such heating applications.

The successful operation of coils of this type depends largely on the mechanical equipment necessary to pass the work to be heated through the coils. The center line of the pieces must coincide with the geometric center of the coil in order to prevent localization of the heat at a particular section unless such a result is desired. In this latter case, such an eccentricity must be precisely maintained for uniformity of product. Also, if the pieces are to be rotated as previously discussed, the axis of rotation of the work itself must be kept in close tolerance or a non-uniform heat pattern will result.

The most simple mechanism for passing work through a coil is a circular turn-table with fixtures for holding the pieces mounted in a circle concentric with the axis of the rotating disc. The coil is then formed to the same radius as the fixtures from the center of the turn-table, and the work to be heated then passes through the center of the coil as the turn-table rotates. Fixtures of this type lend themselves to adaptation for rotating the individual pieces, since a toothed or friction drive to the mounting spindles can be arranged to turn them as the work table rotates.

From this simple fixture, any number of mechanisms can be developed until a very elaborate chain or belt-type conveyor is devised. In many cases, these are necessary to accomplish the desired result, but since they are inherently costly to build and maintain, they should be avoided wherever possible. It is also general practice to include a quenching mechanism in the conveyor when a hardening operation is being performed, and this can either be a spray quench or immersion quench. The spray quench is usually accomplished by mounting a nozzle directly over the path of the work as it leaves the heating coil and having a valve operated by the conveyor mechanism supply quenching medium to the nozzle when a heated piece is directly under it. Immersion quenches are obtained by having the work released or ejected from the holding fixture as it leaves the coil and allowing the work to drop into a container filled with the quenching medium.

Controlled atmospheres to prevent oxidation and other chemical or physical changes are often desired in heating operations of this type. This can be effected by running the conveyor through a muffle containing the desired atmosphere and also having the coil mounted inside the muffle. Thus all the heating takes place within the zone protected by the atmosphere, and the piece is either quenched or cooled before emerging.

Conveyor setups of this type have found many applications in industry. One specific installation performs a brazing operation of a disc-type electrode into the tubular end of an aircraft engine spark-plug. Here the shells, approximately $\frac{5}{8}$" outside diameter, are passed through the coil with the electrode already in place and held in position by gravity. A ring of silver brazing alloy of correct size is previously placed on top of the electrode and brazing flux applied. These components are then passed through the coil at a rate of 18 to 20 per minute, and the brazing performed with uniformity of product resulting in a negligible number of rejected parts.

Another practical application is the heating and subsequent quenching of a small gun part where only two small tips are to be hardened, and the remaining metal left physically unchanged. Here a belt-type conveyor carries the parts through the coil, which is designed in such a manner as to heat only the prescribed sections. The parts, which are of SAE 4150 steel, are ejected from the fixture as they leave the coil and drop into an oil quench.

Hence, in summation, to obtain the full benefits from induction heating, the specific problem should be analyzed to determine whether or not a conveyor type set-up can be utilized. If this is found to be the case, a maximum of production and uniformity of product can be attained with a minimum of labor and operating expense.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Thermocouple selector switches for pyrometer applications are described in new leaflet by Lewis Engineering Co. Bulletin 229.

Control system for hot blast temperatures is described by Brown Instrument Co., and covers new furnaces and those being modernized. Bulletin 244.

HEATING • HEAT TREATMENT

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin 99.

Homo method for nitriding is described and illustrated in new 19-page catalog by Leeds & Northrup. Bulletin 100.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin 102.

Induction heating. Induction Heating Corp. Bulletin 103.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin 104.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin 105.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Hagan rotary forging furnaces are described in bulletin by George J. Hagan Co. Bulletin 108.

Comprehensive, 100-page textbook describes constructional features, capacities, operation and instrumentation of nitriding furnaces. Nitralloy Corp. Bulletin 289.

Centrifugal blowers and exhausters. Roots Connersville Blower Corp. Bulletin 270.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Heavy duty high temperature alloy steel fans are described by Despatch Oven Co. Bulletin 272.

48 illustrated pages describe Precision-Freas constant temperature control cabinets. Precision Scientific Co. Bulletin 273.

"The Trend Is Toward Salt" is title of interesting leaflet showing several examples of heat treatment. Ajax Electric Co. Bulletin 274.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin 290.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

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Other Manufacturers' Literature Listed on Pages 318, 321, 322, 326, 328, 330, 334, and 336.

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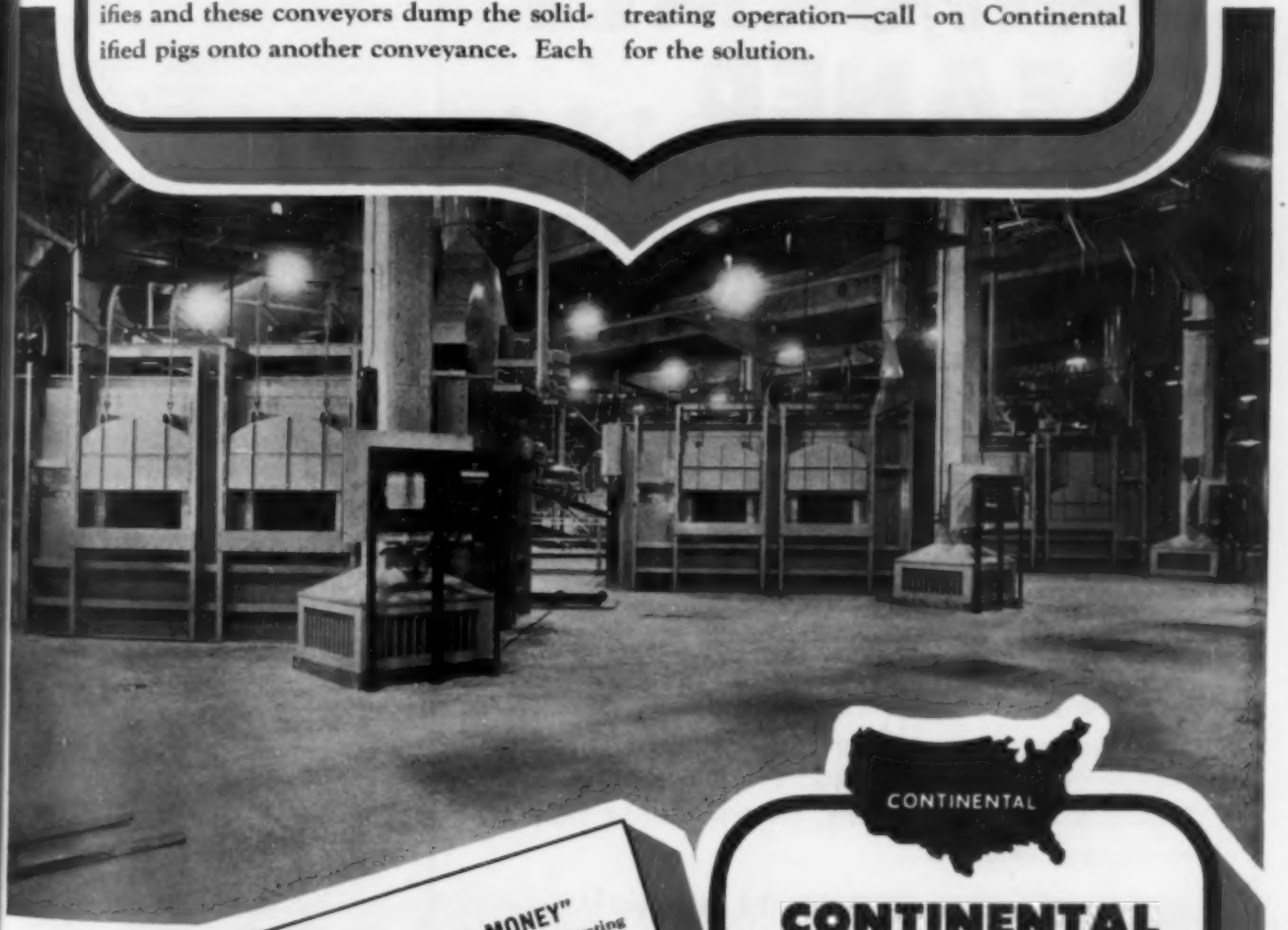

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin 120.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin 121.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Tocco hardening, brazing, annealing and heating machines. Ohio Crankshaft Co. Bulletin 124.

Kleen-well oil strainers for quench oil cooling systems. Bell & Gossett Co. Bulletin 125.

Gas cracking atmosphere unit. Hevi-Duty Electric Co. in new Bulletin 126.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel. United Chromium, Inc. Bulletin 127.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin 129.

Heat treating furnaces. Johnston Mfg. Co. Bulletin 130.

Drycolene. General Electric furnace atmosphere. Bulletin 131.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Industrial Furnaces. W. S. Rockwell Co. Bulletin 133.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Blue Print for Industry is title of new handbook presenting oven engineering information. Industrial Oven Engineering Co. Bulletin 136.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin 138.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin 140.

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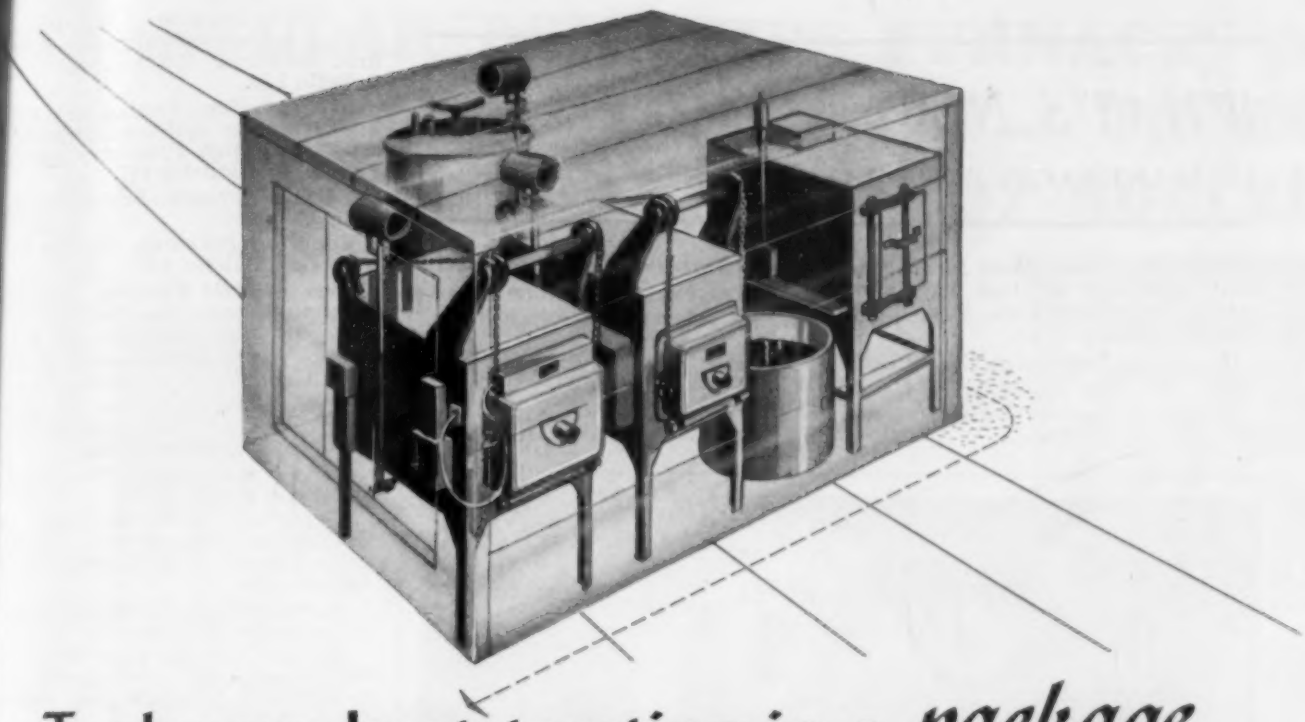

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin 141.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Van Norman induction heating units. Van Norman Machine Tool Co. Bulletin 144.

Flame-hardening, flame-annealing, mechanized-brazing, preheating and other localized open heat treatments. The Selas Co. Bulletin 145.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Newly developed salt bath material for use in Martempering process. E. F. Houghton & Co. Bulletin 151.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Furnace Experience. Flinn & Dreffein Co. Bulletin 153.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin 155.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin 157.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

Turbo-compressors. Spencer Turbine Co. Bulletin 159.

16-page engineering and data booklet on proportioning oil burners, Hauck Mfg. Co. Bulletin 160.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Various Surface Combustion installations engineered for batch carburizing on a production basis are shown in new leaflet. Bulletin 275.

Infra-red gas burners and their advantages are described in new booklet by Burdett Mfg. Co. Bulletin 111.

16-page booklet describes forging furnaces offered by Mahr Mfg. Co. Bulletin 247.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Cromox, a new protective refractory coating material for prolonging the life of firebrick, insulating firebrick, and castable refractories in coal, oil, gas-fired and electric furnaces, as well as in nonferrous melting furnaces. Federal Refractories Corp. Bulletin 163.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Super Refractories catalog. Carborundum Co. Bulletin 165.

Interesting data sheets on Therm-O-Flake insulating bricks and coatings have been issued by Illinois Clay Products Co. Bulletin 298.

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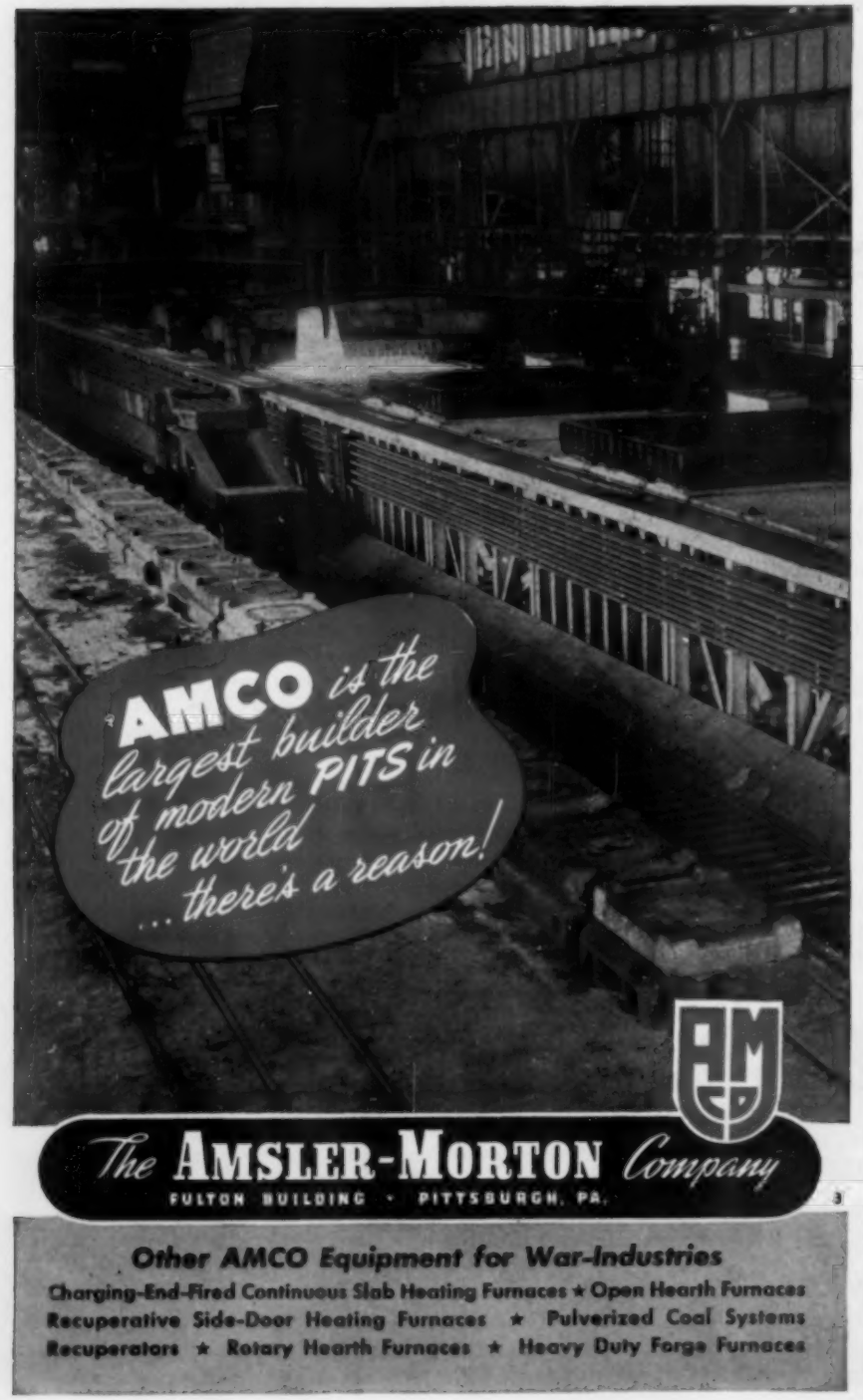
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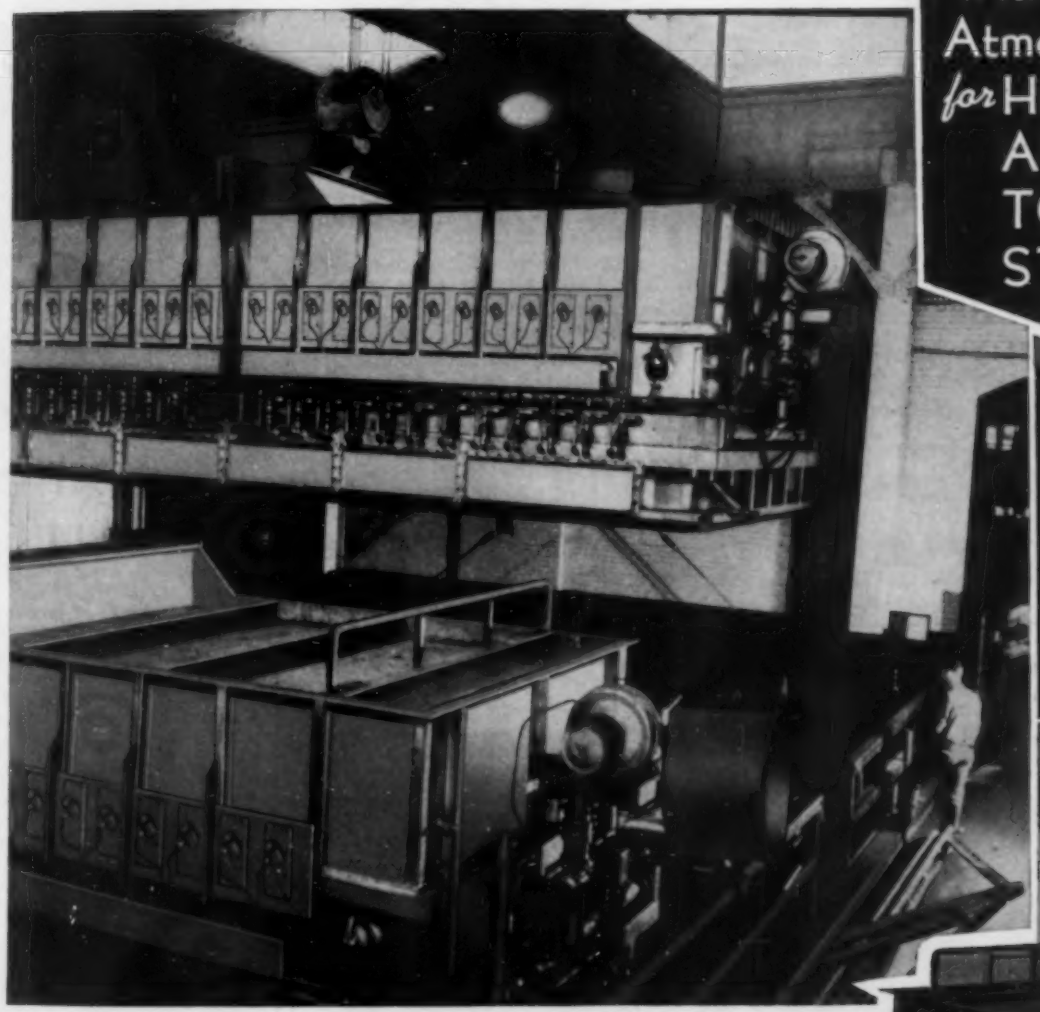

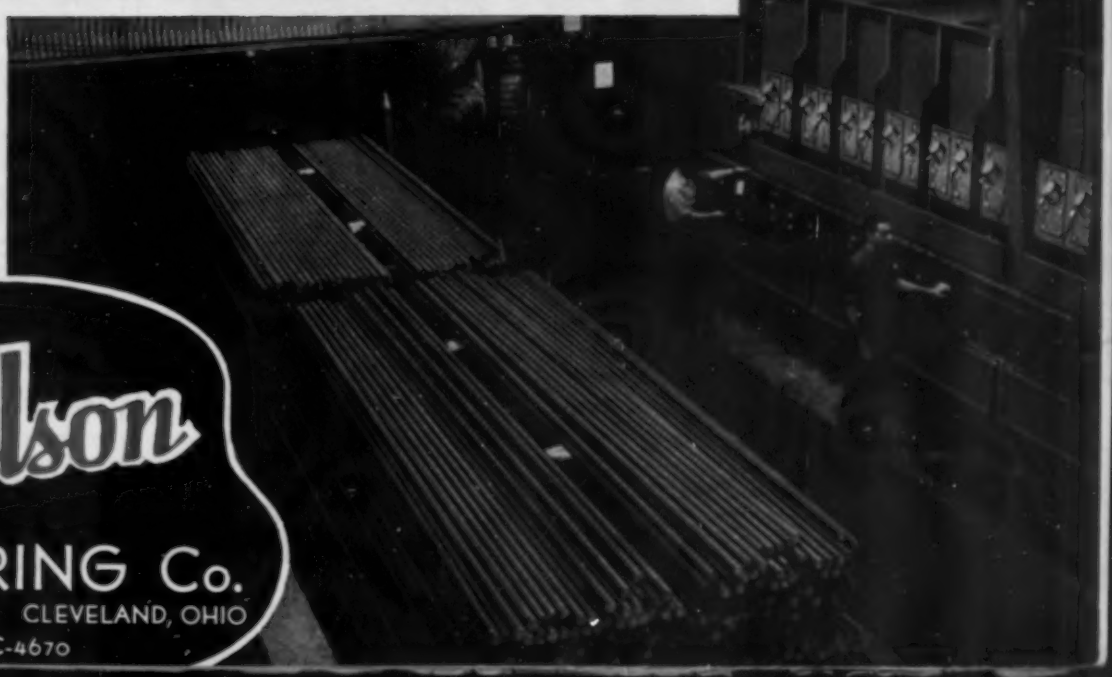

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin 166.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

Ramix bottom for basic open hearth furnaces. Basic Refractories, Inc. Bulletin 168.

Brickseal refractory coating. Brickseal Refractory Co. Bulletin 169.

D-E insulating materials and their

Corhart Electrocast Refractories for the melting and refining of metals are described by Corhart Refractories Co. Bulletin 209.
application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

FINISHING • PLATING • CLEANING

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Four new booklets describe blackening processes for metals. Enthone Co. Bulletin 276.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

Pickling. Wm. M. Parkin Co. Bulletin 174.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

Airless Rotoblast. Pangborn Corp. Bulletin 176.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 177.

Degreasers. Phillips Manufacturing Co. Bulletin 178.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Industrial washing equipment. American Foundry Equipment Co. Bulletin 181.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Well-rounded and helpful catalog on finishing and cleaning has been issued by Frederick Gumm Chemical Co., Inc. Bulletin 292.

Resilon corrosion-resistant tank linings and applications are described in 8-page leaflet by United States Stoneware Co. Bulletin 291.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials to speed and simplify fabrication and surface treatment of stainless steels. Oakite Products, Inc. Bulletin 210.

Anodizing and plating equipment. Lasalco, Inc. Bulletin 211.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

Casting cleaning methods in foundries. N. Ransohoff, Inc. Bulletin 214.

Catalog section on new sheet Koroseal linings for tanks of welded steel, wood or concrete has been issued by the B. F. Goodrich Co. Bulletin 112.

Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

Interesting, illustrated catalog shows typical cleaning and finishing machines engineered and built by Howard Engineering & Mfg. Co. Pickling, tumbling, washing, quenching, drying, burnishing equipment is shown. Bulletin 110.

Four types of solvent degreasers and cleaners are described in new leaflet by Technical Processes Div., Colonial Alloys Co. Bulletin 230.

72-page metal cleaning handbook provides organized means of selecting cleaning materials, methods of use and types of washing equipment. Magnus Chemical Co. Bulletin 231.

Three electronic controllers for plating tanks are described in new folder by Plating Processes Corp. Bulletin 235.

Deoxidine No. 170, for removal of light oil, annealing scale and eradication of rust, is described by American Chemical Paint Co. in Bulletin 236.

New vapor cleaner equipment of Circo Products Company is described in Bulletin 238.

Discussion of anodizing, chromatizing and phosphatizing in illustrated 60-page book has been issued by Turco Products, Inc. Bulletin 243.

MELTING • CASTING • MILL OPERATIONS

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin 184.

Ingot Production. Gathmann Engineering Co. Bulletin 185.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

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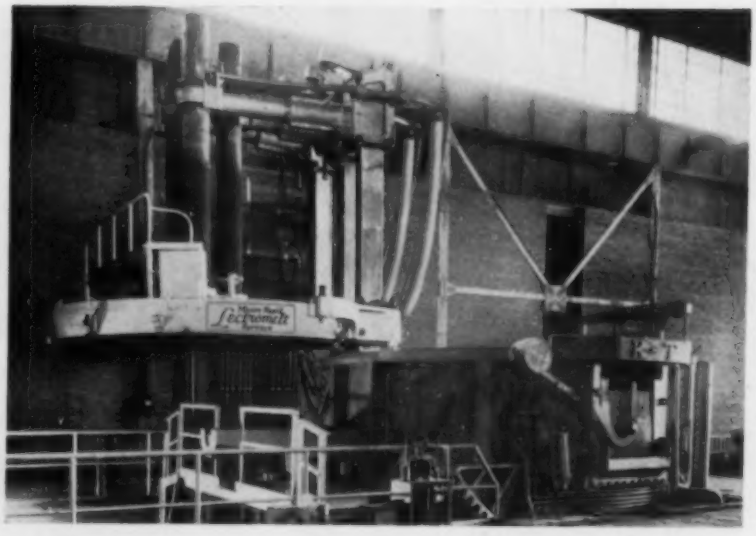

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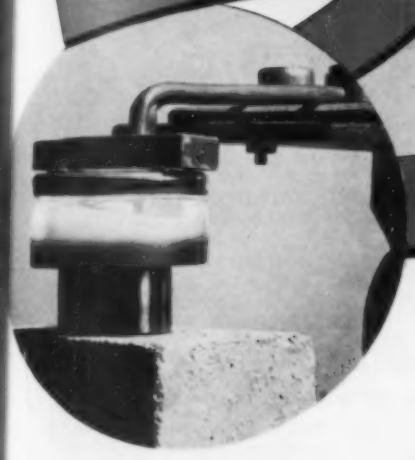

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin 187.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin 188.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin 189.

Stroman crucible melting furnaces for aluminum and magnesium are described in leaflet by Stroman Furnace & Engineering Co. Bulletin 277.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin 216.

Chart for the correction of brasses for zinc loss should interest foundrymen. Foundry Services, Inc. Bulletin 217.

Coke oven plant construction and development in 1942 is described and illustrated in 12-page pamphlet by the Koppers Co. Bulletin 232.

"Fisher Magnesium Scrapbook". Fisher Furnace Co. Bulletin 281.

Attractive booklet describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

ENGINEERING • APPLICATIONS • PARTS

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Centrifugal castings. Shenango-Penn Mold Co. Bulletin 191.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin 194.

12-page booklet describes many specialties of Summerill Tubing Co. Bulletin 282.

Cast bronze, sleeve type standardized bearings. Bunting Brass & Bronze Co. Bulletin 195.

Nichrome and alloy castings. Driver-Harris Co. Bulletin 283.

Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin 284.

Meehanite Castings. Meehanite Research Institute. Bulletin 196.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Metal Baskets. W. S. Tyler Co. Bulletin 198.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Seamless pressed steel heat treating containers. Eclipse Fuel Engineering Co. Bulletin 205.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

48-page catalog on manganese steel. American Manganese Steel Div., American Brake Shoe Co. Bulletin 293.

Alloy Castings. Ohio Steel Foundry Co. Bulletin 207.

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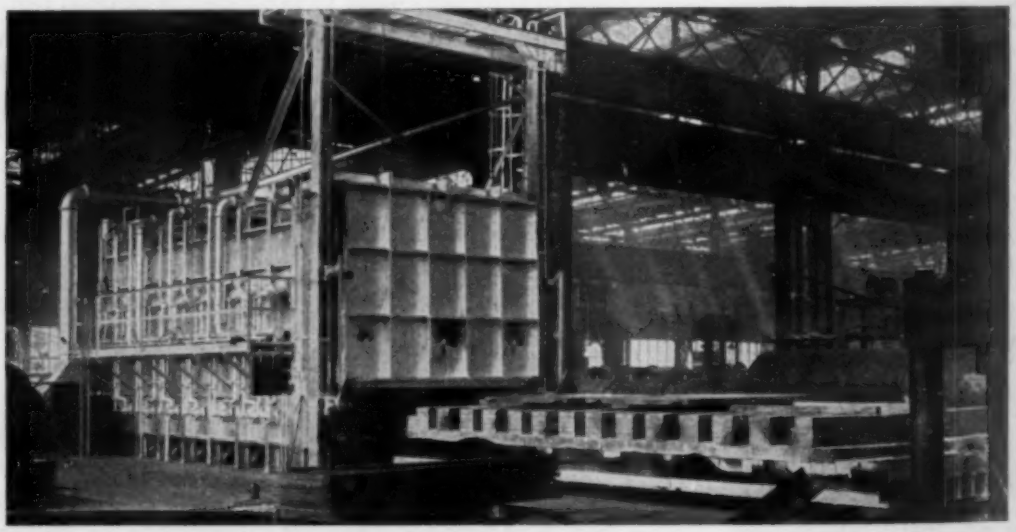

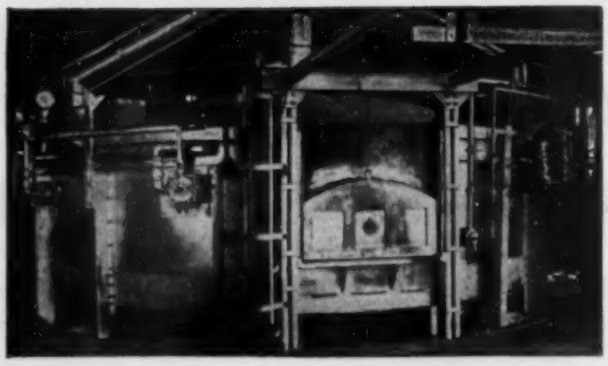

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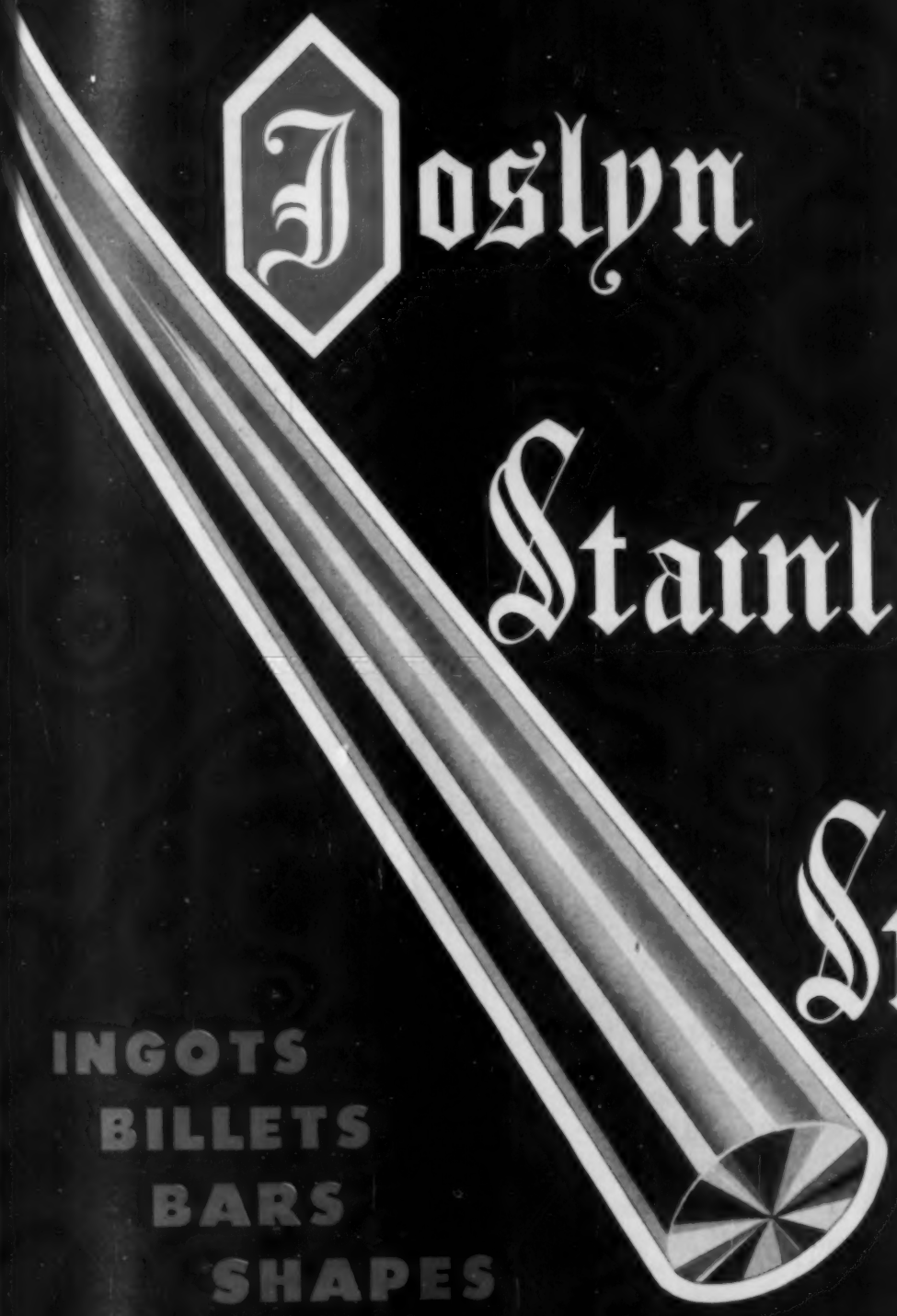

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Spring Design and Engineering is title of new manual issued by Mid-West Spring Mfg. Co. Bulletin 285.

Manual on welded steel tubing for heat exchanger and condenser use has been issued by Formed Steel Tube Institute. Bulletin 286.

New process of tube spinning developed by Wolverine Tube Div., Calumet & Hecla Consolidated Copper Co., is described in brochure just released. Bulletin 287.

An engineer's handbook on electrical contacts. Fansteel Metallurgical Corp. Bulletin 218.

Just released by Atlas Brass Foundry is an 84-page catalog listing sizes and prices of hundreds of finished bronze bushings and porous oil-retaining bearings. Bulletin 219.

Production of gray iron and semi-steel castings is described in an illustrated booklet issued by Forest City Foundries Co. Bulletin 220.

Flanges and other drop forgings. Ladish Drop Forge Co. Bulletin 221.

Finding list and list of sources of alloy metals. Hobart Brothers Co. Bulletin 222.

How to use explosive rivets for high speed blind riveting is set forth in new folder by E. I. du Pont de Nemours & Co. Bulletin 278.

Powder metal oil-retaining porous bronze bearings are described and illustrated in new booklet by Bound Brook Oil-less Bearing Co. Bulletin 279.

Complete line of radial and pivot type bearings is described by Miniature Precision Bearings. Bulletin 280.

Ledaloyl, self-lubricating bearing. Johnson Bronze Co. Bulletin 223.

Metal Powders. Metals Disintegrating Co. Bulletin 224.

Corrosion and heat resistant alloy. Lebanon Steel Foundry. Bulletin 225.

Lead-base metals. Magnolia Metal Co. Bulletin 226.

Oilite precision oil cushion-bronze bearings and other powder metal bar, plate and strip stocks are comprehensively described in 140-page catalog issued by Amplex Div., Chrysler Corp. Bulletin 227.

Many advantages of metal spinning are described and illustrated in leaflet issued by Milwaukee Metal Spinning Co. Bulletin 113.

Facilities and catalog of products are shown in new Ampco Metal, Inc. Bulletin 237.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

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